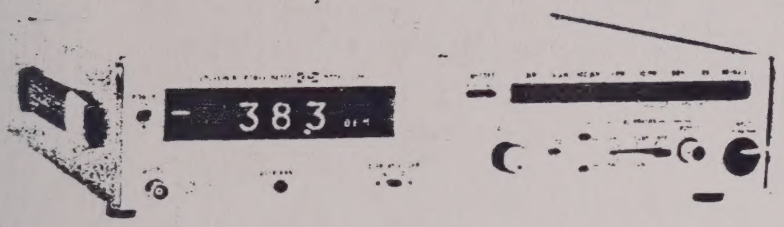
INSTRUCTION MANUAL



LOG/LIN
RF POWER METER

MODEL 1009

SERIAL NUMBER _____

EFFECTIVE IMMEDIATELY
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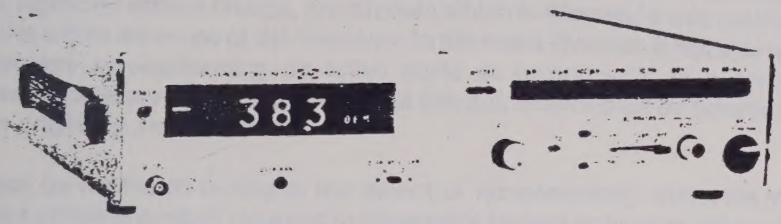
PACIFIC MEASUREMENTS INCORPORATED
470 SAN ANTONIO ROAD, PALO ALTO, CALIFORNIA 94306
TEL: (415) 494-2900 TWX: (910) 373-1171

INSTRUCTION MANUAL



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SECTION 1

GENERAL INFORMATION

1.1 THE PACIFIC MEASUREMENTS MODEL 1009 LOG/LIN RF POWER METER.

The Pacific Measurements Model 1009 Log/Lin RF Power Meter measures RF power level into a 50 ohm input over a frequency range of 10 MHz to 12.4 GHz. A digital display provides convenience and resolution not previously available in a power measuring instrument. Optional BCD outputs allow the Model 1009 to be connected directly to digital acquisition systems. Designed for swept and single frequency measurements, the instrument uses a crystal diode detector to obtain the response speed necessary for swept measurements. Unique circuitry compensates the detector above its square law range so that the Model 1009 accurately measures power levels from −40 dBm to +10 dBm over a temperature range of 18° C to 45° C. Output may be either linear or logarithmic. In the logarithmic mode it is possible to make measurements with 0.1 dB resolution from −40 dBm to +10 dBm without range switching. When making relative measurements in the logarithmic mode, the digital readout may be calibrated to indicate the signal level with respect to an adjustable reference level. Push buttons are used to select the operating mode of the instrument.

1.2 MODEL 1009 PERFORMANCE SPECIFICATIONS.

The specifications of the Model 1009 Log/Lin RF Power Meter are given in Table 1-1.

TABLE 1-1 SPECIFICATIONS

Input:	50Ω, 50 mW max. peak or cw, Type N male connector
Frequency Range:	10 MHz to 12.4 GHz
Signal Level Range:	−40 dBm to +10 dBm
Readout:	3 Digit plus over range in-line digital display
Display Rate:	
Internal:	10 Readings/second
External:	From 0 to 1,000 readings/second by external trigger source
Trigger Input:	A minimum of +3 V lasting at least 5 microseconds is required to trigger the display. Trigger input must fall below +0.5 V to reset the display for a following trigger. Input impedance is approximately 50 kΩ. Maximum input ± 100 V peak.
Operating Modes:	Push-button selected
Linear:	1 μW, 10 μW, 100 μW, 1 mW and 10 mW full scale
Logarithmic:	dBm (absolute), dB (relative), dB-NULL (relative-nulling)
Offset:	Calibrated internal offset ± 60 dB
Accuracy:	(Less frequency response and calibrator inaccuracy)
Linear:	± 5% of reading ± 10 nanoW
Log:	
Absolute:	± 0.3 dB
Linearity:	
Output:	0.2 dB per 10 dB with 0.4 dB max. for a 50 dB change
Digital Display:	As above ± 1 digit in last place
Temperature:	
Operating Range:	18° C to 45° C
Calibration:	Accuracy specifications apply within ± 3° C. of the temperature at which the front panel calibration controls are adjusted.
Frequency Correction Data	Uncertainty of calibration at 1 mW (0 dBm) is 2% to 12 GHz and 3.5% to 18 GHz.
Response Time:	Output will change 50 dB in <600 microseconds for an input change from 10 mW to 0
VSWR Max:	1.2 to 4.5 GHz, 1.35 to 7 GHz, 1.5 to 12.4 GHz
Output Noise:	<0.2 dB peak to peak above −30 dBm <2 dB peak to peak at −40 dBm
Zero Drift:	<10 nW/° C
Analog Output:	Front panel BNC connector, 1 V ± 1% full scale in linear modes. 100 mV/dB ± 1% in log modes.

(Continued)

TABLE 1-1 SPECIFICATIONS (Cont.)

Output Resistance:	1 kΩ
Ratio/Marker Input:	Rear Panel BNC, 100 mV/dB ± 1/2%
Impedance:	Approx. 1 MΩ
Calibrator:	
Frequency:	30 MHz nominal
Power Output:	1 mW ± 1.5%, and 10 μW ± 4%
Power Requirements:	115/230 V ± 10%, 50 - 400 Hz, 25 VA
Physical:	Modular style cabinet for bench mounting
Size:	3.46" H x 16.75" W x 13.00" D
Color:	Blue with contrasting light blue panel
Weight:	Approx. 14 lbs. (6.3 kg), Shipping weight 23 lbs. (10.4 kg).
Option 02:	Extended frequency range to 18 GHz; type APC-7 connector; flatness, ± 1.0 dB to 18 GHz; VSWR, 1.7 12.4 to 18 GHz
Option 03:	
Rear Panel BCD Output:	Provides 4 line 8-4-2-1 BCD code for numerals, a polarity signal, and a print command. Compatible with most printers and computers.
Option 04	75 Ω Input Impedance
Option 05	Isolated BCD Output
Rack Adapter Model 1011	Used to rack mount Model 1009.

SECTION 2
INITIAL INSTRUCTIONS

2.1 POWER REQUIREMENTS.

Units are ordinarily connected at the factory for operation from 105 volts to 125 volts ac at 50 to 400 Hz. Units may be ordered for operation from 210 volts to 250 volts ac if so specified. Conversion from one voltage to the other may be readily made. See Figure 2-1. Reverse the Line Voltage Plate at the rear of the instrument to indicate the voltage for which the unit is wired.

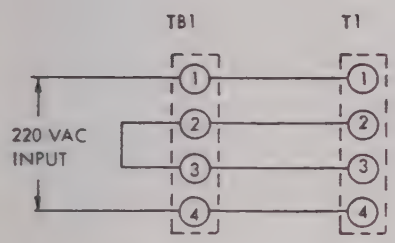


Figure 2-1a

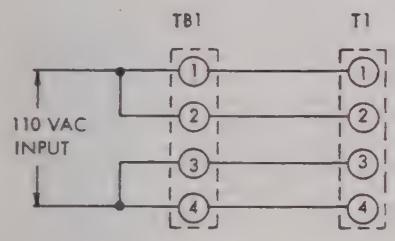


Figure 2-1b

FIGURE 2-1

2.2 CHASSIS GROUNDING.

The instrument is supplied with a three-conductor NEMA type power cord. The instrument will be properly grounded if the plug is connected into a properly installed three-prong receptacle. If a three-prong to two-prong adapter is used, be sure that the pigtail lead of the adapter is grounded.

WARNING

FAILURE TO PROPERLY GROUND THE INSTRUMENT CAN ALLOW DANGEROUS VOLTAGES TO BUILD UP ON THE CHASSIS WHICH COULD BECOME DANGEROUS TO OPERATING PERSONNEL.

The detector shell and the BNC OUTPUT jacks on the front and rear panels are not internally grounded to the chassis in order that the signal ground may be isolated from the power line ground. Thus, if a high voltage is applied to this isolated ground then the detector shell and the outer shell of the BNC OUTPUT connectors may be elevated to a dangerous potential. Care must be taken to insure that signal leads are properly grounded.

2.3 ACCESSORIES.

The following accessories are provided with each Model 1009:

Qty.	Part No.	Description
1	10053	3 Conductor Power Cord
1	--	Instruction Manual

SECTION 3
OPERATION

3.1 FRONT PANEL CONTROLS.

In addition to the POWER switch, the following controls are on the front panel of the instrument.

a. OPERATING MODE PUSH BUTTONS. These eight mechanically interlocked push buttons select the instrument operating mode. The five push buttons on the left are used in the linear mode and perform a range switching function. These push buttons are labeled 1 μW, 10 μW, 100 μW, 1 MW, and 10 MW. The labeling corresponds to the full scale reading of the digital display when this push button is depressed. The remaining three push buttons are labeled DBM, DB, and DB-NULL. When the DBM push button is depressed, the instrument will indicate absolute power in DBM. When either the DB or DB-NULL push buttons are depressed, the instrument indicates relative power in dB. In the DB mode the digital display indicates the input relative power in dB, while in the DB-NULL position, the digital display indicates the null offset in dB.

b. OFFSET CONTROL AND OFFSET SELECTOR LEVER. The OFFSET control is used to set the level of offset and is used only in the DB and DB-NULL operating modes. The OFFSET control is used to adjust either one of two offset potentiometers, as determined by the OFFSET selector lever. Both potentiometers are ten-turn units having a control range of at least ± 60 dB. With the OFFSET selector lever in the REF position, the OFFSET control is used to zero the output voltage when the detector RF input is at the 0 dB, or reference level. With the OFFSET selector lever in the NULL position, the OFFSET control is used to measure a power level with respect to the reference power level. The OFFSET NULL position is active only in the DB-NULL mode.

c. CALIBRATOR SWITCH. This three-position lever switch controls the RF level on the CALIBRATOR OUTPUT jack. Its three positions are OFF, -20 DBM (10 μW), and 0 DBM (1 MW).

d. LOG CALIBRATE ADJUSTMENT (0 DBM). This is a screwdriver adjustment active only in the DBM operating mode and is used to calibrate the instrument for absolute power measurement in the logarithmic mode.

e. LINEAR CALIBRATE ADJUSTMENT (1 MW). This screwdriver adjustment is used to calibrate the instrument in the linear operating modes.

f. DISPLAY FILTER SWITCH. This slide switch has two positions, IN and OUT. With this switch in the IN position, a low pass filter is placed in the digital display input to smooth the digital display when measuring noisy, low level signals. With this switch in the OUT position, the low pass filter is removed and the digital display is free to respond rapidly to changing signal levels.

g. ZERO ADJUSTMENT. This screwdriver adjustment is used to set the digital display to read 0.000 μW when the input is zero.

h. OUTPUT GROUNDING SWITCH. This slide switch has two positions, INT (internal) and EXT (external). With this switch in the INT position the isolated shells of the OUTPUT jacks and the Ratio/Markers INPUT jack are connected to the outer conductor of the INPUT type N connector. With the switch in the EXT position the shells are isolated from the outer conductor of the INPUT connector.

3.2 REAR PANEL CONTROL

DISPLAY TRIGGER SWITCH. This two-position slide switch selects the source of the display trigger. In the INTERNAL position the display is triggered by an internal 10 Hz source. In the EXTERNAL position the display is triggered by a source connected to the rear panel EXTERNAL TRIGGER INPUT jack.

3.3 FRONT PANEL INDICATORS.

a. OVER RANGE LIGHT. This light is active only in the linear operating modes. When lit, it indicates that the power measuring circuitry is overloaded and that the instrument reading is no longer accurate.

b. DIGITAL DISPLAY. Display tubes are used to indicate polarity and three digits plus one over-range digit. The measurement units are indicated directly to the right of the numerical display. The units are μW, MW, DB, and DBM.

3.4 FRONT PANEL CONNECTORS

a. OUTPUT JACK. This BNC jack furnishes +1 V for a full scale reading in the linear mode. In the logarithmic mode, its output level is 10 DB/V. Output resistance is 1 k ohm ± 1%. The shell of this jack is isolated from the power line ground. Refer to Sections 2.3 and 5.6 for information regarding grounding the instrument.

b. CALIBRATOR OUTPUT JACK. This type N jack furnishes 30 MHz RF power for calibrating the instrument. Output is determined by the CALIBRATOR switch and is either OFF, -20 dBm (10μW), or 0 dBm (1 mW).

3.5 REAR PANEL CONNECTORS.

a. OUTPUT JACK. This BNC jack is connected in parallel with the front panel BNC OUTPUT jack. The shell of this jack is isolated from chassis ground so that the signal ground may be isolated from the power line ground. Refer to Sections 2.3 and 5.6 for information regarding grounding the instrument.

b. RATIO/MARKERS INPUT JACK. This BNC jack may be used to inject a signal into the Model 1009 output for ratioing purposes or to provide a video frequency marker. Input sensitivity is 100 mV/dB and input resistance is approximately 1M ohm. This sensitivity and input resistance allows two Model 1009 units or a Model 1009 and a Model 1015, Log RF Power Monitor, to be used together for ratioing two RF signals without the need for any adjustments. A positive going signal in this input causes a negative going output signal. This input jack is active only in the DB and DB-NULL modes.

c. EXTERNAL TRIGGER INPUT JACK. This BNC input is used for triggering the digital display by an external source when the DISPLAY TRIGGER switch is in the EXTERNAL position. The display may be triggered at any rate from 0 to 1000 readings/second. A +3 V signal

lasting for at least 5 microseconds is required to trigger the display. Trigger input must fall below +0.5 V to reset the display for a following trigger. Input impedance is approximately 50 k ohm.

3.6 RF DETECTOR

The crystal diode type microwave detector has a type N male INPUT connector and is permanently attached to a three foot input cable. A temperature compensating thermistor is mounted in the detector case. The RF input impedance is 50 ohms. When the detector is not in use, it may be protected from damage by pushing the cable and detector into the holder on the front panel of the instrument.

3.7 OPERATING PROCEDURE.

CAUTION

Continuous or peak power levels in excess of +17 dBm (50 mW) can damage the crystal diode in the detector. Always take precautions to insure that the detector input will be well below this power level before connecting it to a source of RF power.

3.7.1 SINGLE FREQUENCY OPERATION.

a. Connect the line cord. Be sure that it is properly grounded. Refer to Section 5.6 for grounding precautions to be taken for measuring low level signals.

b. Set the rear panel DISPLAY TRIGGER switch to get the desired digital display rate. If the display rate is to be triggered by an external source, make sure the trigger input is at least +3 V, 5 microseconds wide, and falls below 0.5 V during each cycle.

c. Turn the POWER switch to ON. The digital display should light immediately.

d. After a fifteen minute warmup, depress the 1 μW push button and check that the digital display reads 0.000 μW with zero input. If it does not, set the digital display to read 0.000 μW using the ZERO adjustment.

e. Connect the detector to the CALIBRATOR OUTPUT jack. Depress the 1 MW push button and set the CALIBRATOR switch to the 1 MW position. Place the DISPLAY FILTER switch in the OUT position.

f. Set the LIN CAL adjustment so that the digital display indicates 1.000 MW.

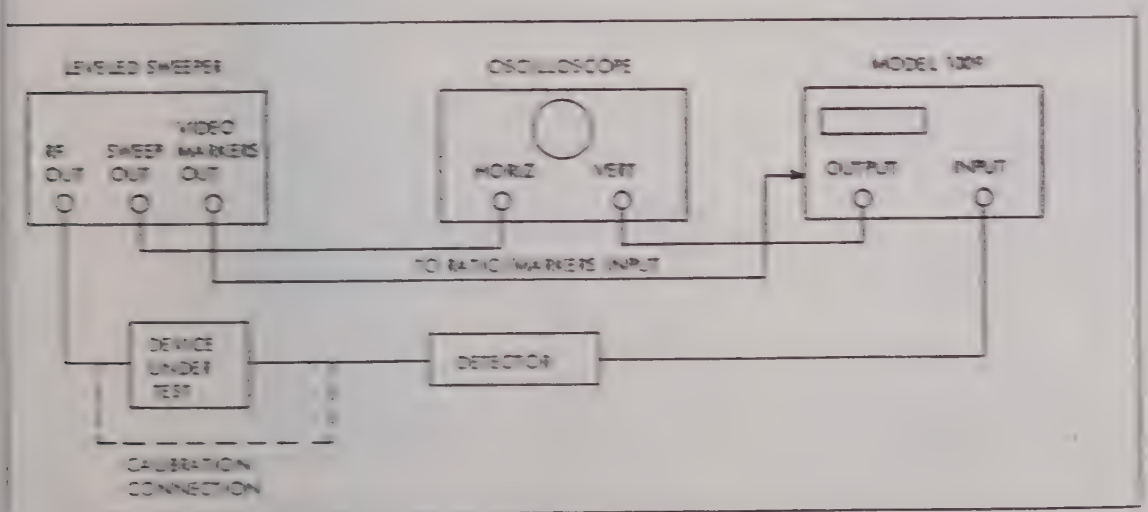
g. Depress the DBM pushbutton and set the LOG CAL adjustment so the digital display reads 00.0 DBM.

h. The -20 DBM (10 μW) position on the CALIBRATOR switch may be used to check whether the detector is functioning properly or has been inadvertently damaged.

i. Remove the detector from the CALIBRATOR OUTPUT jack and connect it to the desired measuring point. The measured power level is indicated in dBm on the digital display. To measure in the linear mode, depress the linear mode push button which will result in the largest on scale digital display reading. If measuring low power levels or noise makes the digital display difficult to read, move the DISPLAY FILTER switch to the IN position.

j. To make relative power measurements in the DB mode, connect the detector to the point in the test circuit where the power level is at the reference, or 0 dB, level. If, for example, the Model 1009 is to be used to measure the gain or loss of a device, then the reference power level is the level at the input of the device under test. Depress the DB pushbutton and move the OFFSET selector level to the REF position. Turn the OFFSET control to obtain a digital display reading of 00.0 DB. Place the OFFSET selector lever in the NULL position so that inadvertent movement of the OFFSET control will not require resetting of the offset reference potentiometer. Connect the detector to the desired measuring point. Power level variations from the reference level are now indicated in dB on the digital display.

3.7.2 SWEPT FREQUENCY OPERATION. In sweep frequency operation, an oscilloscope is used in conjunction with the Model 1009 and a sweep frequency source drives the measurement system. Figure 3-1 shows typical connections for making sweep gain or loss measurements.



TYPICAL CONNECTIONS FOR SWEPT GAIN OR LOSS MEASUREMENT

FIGURE 3-1

a. Connect the line cord. Be sure that it is properly grounded. Refer to Section 5.6 for grounding precautions to be taken for measuring low level signals.

b. Set the rear panel DISPLAY TRIGGER switch to get the desired digital display rate. If the display rate is to be triggered by an external source, make sure the trigger input is at least +3 V, 5 microseconds wide, and falls below 0.5 V during each cycle.

c. Turn the POWER switch to ON. The digital display should light immediately.

d. After a fifteen minute warmup, depress the 1 μW push button and check that the digital display reads 0.000 μW with zero input. If it does not, set the digital display to read 0.000 μW using the ZERO adjustment.

e. Connect the detector to the CALIBRATOR OUTPUT jack. Depress the 1 MW push button and set the CALIBRATOR switch to the 1 MW position. Place the DISPLAY FILTER switch in the OUT position.

f. Set the LIN CAL adjustment so that the digital display indicates 1.000 MW.

g. Depress the DBM push button and set the LOG CAL adjustment so the digital display reads 00.0 DBM.

h. Balance the oscilloscope vertical input and set the vertical position control to get 0 V deflection for 0 V of vertical input. Connect the Model 1009 OUTPUT jack to the oscilloscope vertical input, observing grounding precautions as noted in Section 5.6 Connect the sweep output of the signal source to the oscilloscope horizontal input. If the oscilloscope inputs are not isolated from each other and ground, it is best not to connect the oscilloscope and signal generator ground leads. Refer to Section 5.6

i. Connect the sweeper video marker output to the RATIO/MARKER INPUT jack. If the marker amplitude is not adjustable at the sweeper and if the markers are objectionably large, an attenuator may be placed between the marker output of the sweeper and the RATIO/MARKER INPUT.

j. Energize the sweeper and adjust it to the desired operating conditions.

k. Depress the DB push button and connect the detector to the reference (0 dB) power point. Figure 3-1 shows the calibration connection when making gain or loss measurements. Adjust the oscilloscope vertical sensitivity to 0.5 dB/division (50 mV/division). Be careful not to disturb the oscilloscope vertical position control, since the horizontal center line on the oscilloscope is the zero reference. Place the OFFSET selector lever in the REF position and use the OFFSET control to center the reference trace on the oscilloscope display. Place the OFFSET selector lever in the NULL position. Remove the detector from the reference power point and connect it to the desired measuring point. Adjust the oscilloscope display for the most convenient presentation. The digital display reading is not useful when sweeping rapidly in the DB mode.

l. At low detector signal levels, the response of the Model 1009 may not be fast enough to accommodate rapid changes in signal level. Thus, the swept waveform may become distorted for fast sweeps. Check to insure that this distortion is not present by varying the sweep speed. If the shape of the swept display changes when the sweep rate changes, then the sweep rate is too fast and must be decreased. If the shape of the swept display on the oscilloscope is independent of sweep rate, then no distortion is present.

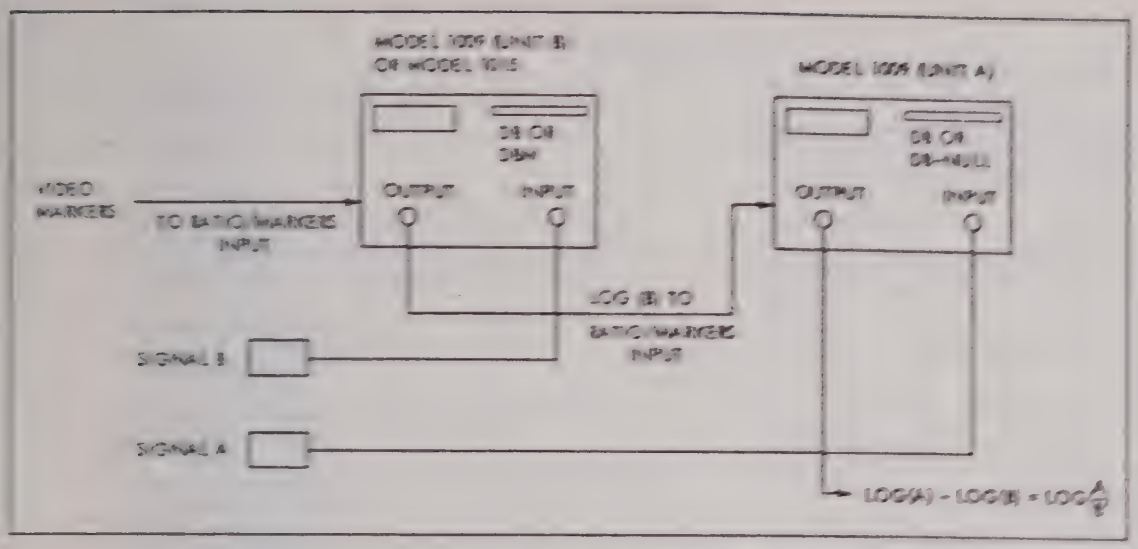
m. The deviation from the 0 dB reference level of any point on the swept display may now be measured by switching the sweeper to single frequency operation at the frequency of the point of interest and reading the variation, in dB, on the digital display. For sweepers which have single frequency operating points set by their video markers, this method is very convenient. Simply move the marker to the point of interest on the oscilloscope waveform, switch to single frequency operation at the marker frequency, and note the digital display reading.

n. Measurements in the DB-NULL mode are made by comparing a signal level on the swept waveform against the offset of the Model 1009. In this mode, the measurements are made with the sweeper set for swept operation and the digital display reads the offset rather than the voltage on the OUTPUT jack. Depress the DB-NULL push button. The variation of any point on the swept waveform from the reference (0 dB) power level is measured by placing this point on the horizontal center line of the oscilloscope display by using the OFFSET control. The digital display now indicates the difference between the reference power and the measured power. Note that the oscilloscope horizontal center line represents 0 V and that vertical sensitivity must be high enough for accurate nulling. The Model 1009 output level is 100 mV/dB in the log modes. An oscilloscope vertical sensitivity setting of 50 mV/division results in a display sensitivity of 0.5 dB/division, which should be adequate. The DB-NULL mode is also convenient for viewing part of a widely varying signal at high sensitivity. The offset allows any part of any signal within the operating range of the instrument to be centered on the oscilloscope screen regardless of the display sensitivity.

o. The oscilloscope screen may be calibrated in terms of absolute power by depressing the DBM push button. The horizontal center line represents 0 dBm and the display sensitivity is a function of the vertical sensitivity of the oscilloscope. A vertical sensitivity setting of 1 V/division would result in a display sensitivity of 10 dB/division. The digital display reading is not useful when sweeping rapidly in this mode.

p. Linear operation of the Model 1009 for swept measurements results in the oscilloscope screen being calibrated for absolute power measurements also. In linear operation the Model 1009 OUTPUT furnishes 1 V full scale. The display sensitivity depends on the Model 1009 full scale range as well as the oscilloscope vertical sensitivity. For example, if the 100 μW push button is depressed and the oscilloscope vertical sensitivity is set at 100 mV/division, then the display sensitivity is 10 μW/division.

3.7.3 RATIOING. Two Model 1009 units or a Model 1009 and a Model 1015, Log RF Power Monitor, may be used to ratio two signals in the log mode in either swept or single frequency operation. Test connections for ratioing the signals are shown in Figure 3-2. The Model 1009 has been designed so that no sensitivity adjustments are required when two instruments are used to make ratio measurements. However, it is important that the offset reference potentiometers of the instruments be set so that the output signals of both instruments are within 6 V of ground at all times, when both instruments are in the DB mode. The ratioed signal may be measured in



CONNECTIONS FOR RATIOING
TWO SIGNALS

FIGURE 3-2

the DB or DB-NULL mode by depressing the appropriate push button of the Model 1009 (Unit A, Figure 3-2). The second Model 1009 or Model 1015 (Unit B, Figure 3-2) is operated in the DB or DBM mode.

SECTION 4

PERFORMANCE CHECKS

4.1 EQUIPMENT REQUIRED FOR PERFORMANCE CHECKS.

a. A dc voltmeter capable of measuring 12.6 V within 0.01%.

b. A power signal source having a frequency somewhere between 10 MHz and 30 MHz with at least 10 mW minimum power output. Output power must be adjustable so that an output of 10 mW ± 10 µW may be obtained.

c. A step attenuator having a 0 to 50 dB insertion loss range and calibrated to 0.05 dB at the frequency of the signal source.

d. A stable, adjustable dc source with the capability of setting 1 V ± 0.1%.

e. An RF power meter, 50 ohms input impedance, capable of measuring 1 mW and 10 µW to 1% at 30 MHz.

f. A 1 MHz oscilloscope having a vertical sensitivity of at least 10 mV/division.

NOTE: All performance checks must be performed with the ambient temperature between 65°F (22°C) and 100°F (45°C).

4.2 CALIBRATOR CHECK.

Connect the line cord and turn the POWER switch to ON. Connect the power meter to the CALIBRATOR OUTPUT jack and measure the calibrator power output at 1 mW and 10 µW. With the CALIBRATOR switch in the 10 µW position, the power meter should read 10 µW ± 4%. With the CALIBRATOR switch in the 1 MW position, the power meter should read 1 mW ± 2.5%.

4.3 POWER MEASUREMENT CHECKS.

4.3.1 LINEAR MODE.

a. After a fifteen minute warmup, depress the 1 µW push button and check that the digital display reads 0.000 µW with zero input. If it does not, set the digital display to read 0.000 µW using the ZERO adjustment.

b. Calibrate the Model 1009 for linear measurement at 1 mW by connecting the detector to the CALIBRATOR OUTPUT jack, depressing the 1 MW push button, setting the CALIBRATOR switch to the 1 MW position, placing the DISPLAY FILTER in the OUT position and setting the LIN CAL adjustment so that the digital display indicates 1.000 MW.

c. Set the attenuator for 10 dB insertion loss and connect it between the signal source and the Model 1009 INPUT. Adjust the signal source to get a reading of 1.000 MW on the Model 1009 digital display.

d. Depress the 10 MW push button and set the attenuator insertion loss at 0 dB. The Model 1009 digital display should now read 10.00 MW ± 0.50 MW + attenuator error.

e. Set the attenuator insertion loss to 20 dB and depress the 100 µW push button. The digital display should read 100.0 µW ± 5 µW + attenuator error.

f. Set the attenuator to 30 dB insertion loss and connect the detector to the attenuator output. The digital display should read 10.00 µW ± 0.50 µW + attenuator error.

g. Set the attenuator to 40 dB insertion loss and depress the 1 µW push button. The instrument should indicate 1.000 µW ± 0.050 µW + attenuator error.

h. Check and reset zero.

i. Set the attenuator insertion loss to 50 dB. The digital display should read 0.100 µW ± 0.005 µW + attenuator error.

4.3.2 ABSOLUTE POWER LOGARITHMIC MODE.

a. After a fifteen minute warmup, depress the 1 µW push button and check that the digital display reads 0.000 µW with zero input. If it does not, set the digital display to read 0.000 µW using the ZERO adjustment.

b. Calibrate the Model 1009 for absolute power measurement at 0 dBm by connecting the detector to the CALIBRATOR OUTPUT jack, depressing the DBM push button, setting the CALIBRATOR switch to the 0 DBM position and setting the LOG CAL adjustment so that the digital display indicates 00.0 DBM.

c. Set the attenuator for 10 dB insertion loss, connect the detector to the attenuator output and adjust the signal source so that the digital display reads 00.0 DBM.

d. Set the attenuator insertion loss at 0 dB. The digital display should read +10.0 DBM ± 0.3 dB + attenuator error.

e. Set the attenuator at 20 dB. The digital display should indicate -10.0 DBM ± 0.3 dB + attenuator error.

f. Set an insertion loss of 30 dB on the attenuator. The digital display reading should be -20.0 dBm ± 0.3 dB + attenuator error.

g. Set 40 dB insertion loss into the attenuator. The digital display reading should be -30.0 dBm ± 0.3 dB + attenuator error.

h. Set the attenuator for 50 dB insertion loss. The digital display should read -40.0 dBm ± 0.3 dB + attenuator error.

i. Connect the oscilloscope to the Model 1009 OUTPUT jack. Set the GROUNDING switch to the EXT position. The signal variation shown on the oscilloscope screen should be less than 200 mV peak to peak (2dB peak to peak.)

j. Set 40 dB of insertion loss on the attenuator. The peak to peak signal variation shown on the oscilloscope should now be less than 20 mV (0.2 dB). Above -30 dBm (40 dB insertion loss) noise should be less than 0.2 dB.

4.3.3 RELATIVE POWER LOGARITHMIC MODE.

a. Set the attenuator insertion loss to 0 dB and adjust the signal source to get 10 mW at the attenuator output.

b. Depress the DB-NULL push button and place the OFFSET selector lever in the NULL position. Set the Model 1009 digital display to read 00.0 DB by means of the OFFSET control.

c. Connect the detector to the attenuator output. Depress the DB push button and place the OFFSET selector lever in the REF position. Set the Model 1009 digital display to read 00.0 DB by means of the OFFSET control.

d. Connect the precision power supply to the RATIO/MARKER INPUT jack. The digital display should change 10.0 dB when the power supply voltage is changed from 0.00 V to 1.00 V.

SECTION 5
APPLICATION INFORMATION

5.1 GENERAL.

The digital display and the fast response detector of the Model 1009 enable the user to make single frequency and swept RF power measurements with ease and resolution not previously possible. Square law compensation of the detector and the use of logarithmic output allows measurements from 0.1 μW to 10 mW without range switching. The frequency range of 10 MHz to 12.4 GHz makes the instrument useful in many communication bands as well as in the microwave region.

5.2 GAIN/LOSS MEASUREMENTS.

The Model 1009 is a basic tool for making either swept or single frequency gain or loss measurements. The most convenient operating mode for these measurements is the DB mode where the readout may be calibrated to read the desired power variation directly. For instance, if the gain of an amplifier is to be measured, the 0 dB or reference level is its input power level. If the input power is always 0 dB, then the output power, measured in dB, is the gain of the amplifier. The calibration procedure is to replace the amplifier in the measuring system with a direct connection as indicated in Figure 3-1, and set the Model 1009 OUTPUT to 0 by means of the REF OFFSET control. Gain or loss measurements may be made in the linear mode as well. In calibrating the Model 1009 for gain or loss measurements in the linear mode, set the signal source so that the output is easily related to the gain or loss of the tested device. For example, in measuring the gain of an amplifier, if the input power is set to 1 μW, then the amplifier output, measured in microwatts, is numerically equal to the amplifier gain.

5.3 REFLECTOMETER MEASUREMENTS.

A typical reflectometer set up for making swept VSWR measurements is shown in Figure 5-1. The objective is to measure the ratio of power reflected from, to power incident on the input of the device under test. This ratio, expressed in dB, is called the Return Loss. The following equations relating Return Loss, Reflection Coefficient, ρ, and VSWR are pertinent.

(1) Return Loss = 20 Log ρ (2) VSWR = $\frac{1 + \rho}{1 - \rho}$

A well matched junction results in little power being reflected and the ratio of reflected to incident power is low. A poorly matched junction results inappreciablepower reflection. To calibrate the reflectometer system for return loss measurements, replace the device under test by a short circuit. Since the short circuit is a perfect mismatch, reflected power equals incident power and return loss is 0 dB. This calibration procedure will also indicate the matching of the incident and reflected power couplers. If the coupling factors of both of these couplers are perfectly matched and the leveling detector is flat, then the calibration curve should be essentially a straight line on the oscilloscope display. This calibration line should be set to 0 by means of the REF OFFSET control. To make the measurement, replace the short with the device to be tested.

If the impedance of the reflectomer system, as seen by the device under test looking back toward the generator is not a perfect Z_o match, an appreciable error can result. The most serious component of the error occurs during calibration with a short circuit. This error can be minimized by either of two simple techniques: (1) A sliding short may be used, and the system response viewed for all phases of reflection; the average response should be taken as the calibration level.

(2) A known mismatch can be used to obtain a calibration level. A 6 dB attenuator makes a handy mismatch when terminated in a short circuit. The return loss of 12 dB is sufficiently high to minimize the problem of multiple reflections, yet provides enough signal that no appreciable error is introduced by finite coupler directivity. Of course the calibration level is now -12 dB instead of 0 dB, and proper account must be taken of this (with the Pacific Measurements Model 1009 it is simply required to adjust the internal reference level accordingly).

For reflectometer measurements, two matched directional couplers are used to eliminate errors caused by coupling factor variations with frequency. However, to subtract out the coupling factor variations, the incident power coupler must be used to level the sweeper as shown in Figure 5-1. If the sweeper is internally leveled, then the coupling factor variations in the reflected power coupler must be accounted for in the calibration procedure. Another possibility is to ratio the reflected power to the incident power by using another Model 1009, or Model 1015, Log RF Power Monitor, whose detector is connected to the incident power coupler.

The accuracy of swept reflectometer measurements depends mostly on the quality of the reflectometer couplers. Where the measured mismatch is low, the directivity of the reverse power coupler determines the error. Directivity is a measure of the incident power which leaks into the reverse power coupler. Error due to the Model 1009 is less than 0.02 dB/dB of return loss measured and is comparable to the error introduced by an excellent coupler. Figure 5-2 shows the error in return loss due to the coupler directivity.

5.4 USE WITH DATA ACQUISITION SYSTEMS.

An optional 24 pin rear panel connector furnishes the BCD outputs of the digital display. This allows connection of the Model 1009 to data acquisition systems without the need for any interfacing instrumentation. The four line output of each digit is presented in an 8 4 2 1 code, additional outputs are provided for polarity and a print command. When connected to a data acquisition system the display is triggered through the rear panel DISPLAY TRIGGER INPUT. A +3 V, 5 microsecond signal is required to initiate the measurement cycle which is approximately 400 microseconds long. To reset the trigger circuitry, the triggering waveform must fall below 0.5 V during each cycle. The waveform of this trigger input is relatively arbitrary. A sine wave, a pulse train, a square wave, or a saw tooth are all satisfactory for triggering the display. At the completion of the measurement cycle, a signal appears on the print command output informing the data acquisition system that the reading may be recorded. The speed of the measurement cycle permits the instrument to make up to 1000 measutements/second.

5.5 DETECTOR POWER LEVELS.

When making relative power measurements the Model 1009 OUTPUT does not indicate the power level at the detector. The detector power level must be inferred from the Model 1009 OUTPUT through knowledge of the absolute level of the reference power level. Because of noise and zero drift at low level and because level compensation becomes inaccurate at high levels, care must be taken in measurements at very low levels and above +15 dBm. At low signal levels the measurement boundary may be indicated by an excess of noise on the OUTPUT, but at signal levels above +15 dBm, there is no simple indication. If in doubt about a relative power measurement for this reason, check the absolute power level on

the detector by putting the Model 1009 in the DBM mode. When making swept measurements, place the sweeper in single frequency operation at the point of interest before switching to the DBM mode. It is also well to remember that at low power levels, -30 dBm and below, the response of the Model 1009 is slowed. For this reason, use the highest detector power level that the system will allow for the best response.

5.6 GROUNDING.

Both the detector shell and the OUTPUT BNC shell are isolated from the chassis ground and are common to the floating ground of the instrument. The purpose of isolating these shells from the power line ground is to permit the operator to make signal ground independent of the power line ground and, thus avoid difficulties with unwanted power line signals being induced or conducted in the signal leads. It is important that a good signal ground be made somewhere in the system so that large or dangerous potentials will not appear on the outer conductors of the input and output cables. Care must be taken to assure that no power line currents flow through the signal leads. This may be readily accomplished through use of the OUTPUT GROUNDING switch. With the switch in the EXT position, the OUTPUT connector shells and the RATIO/MARKERS INPUT connector shell are isolated from the INPUT type N connector shell. This prevents ground currents from flowing through the signal leads of the Model 1009. With the OUTPUT GROUNDING switch in the INT position the shells are connected together.

The crystal detector input of the Model 1009 is extremely sensitive, so that unwanted signals amounting to a small fraction of a millivolt will cause serious errors when measuring small RF input signals. On the other hand, the output voltage from the Model 1009 is quite large, amounting to 100 millivolts per decibel input change. Ordinarily, ground voltages between the oscilloscope and the Model 1009 will be much less than 100 millivolts. Consequently, a separate ground tie between the oscilloscope and the Model 1009 is not normally required. It is, however, necessary that the oscilloscope have some ground of its own. Normally, this is accomplished by connecting the oscilloscope horizontal input, together with its ground, to the sweep output of the signal source supplying the microwave measurement system. In addition, the oscilloscope power-cord ground may be used to make contact with the bench ground. This will permit the filter capacitors on the line interference filter to be returned directly to bench ground. These connections will normally result in a few millivolts ac potential between the oscilloscope and the Model 1009, but the oscilloscope need not be operated at an input sensitivity of greater than 50 millivolts per centimeter, and this parasitic voltage will be unnoticed.

Since the shell of the DISPLAY TRIGGER INPUT is isolated, a shielded cable may be connected to this connector. It is extremely important to remember that signals being measured below -30 dBm are extremely low level. Effects due to dc voltage drop through resistive connections, ground carrying power supply currents, and thermal voltages can become very important.

5.7 LEVELING.

Since long RF cables between the signal source and the measurement circuit can introduce fairly serious frequency sensitive signal level deviations, leveling of the signal source should be done as close as possible to the point of measurement. The best method is to use a signal source which may be externally leveled. Leveling may be accomplished by means of a coupler matched to the coupler used to furnish input to the Model 1009 detector as in Figure 5-1 or by means of a very flat coupler. In any case, leveling should be accomplished in such a manner as to minimize tracking errors.

5.8 SWEPT MEASUREMENTS.

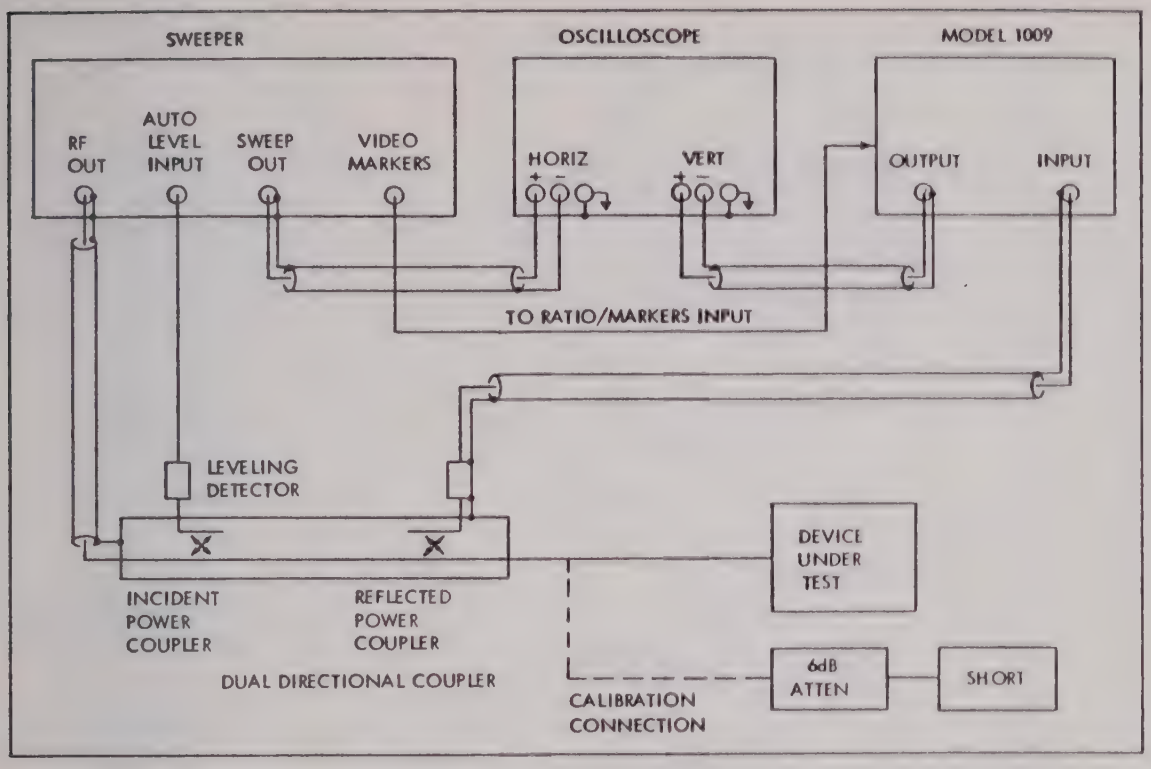
The following considerations are pertinent when using the Model 1009 in conjunction with a sweeper and an oscilloscope to make swept measurements.

a. CHOICE OF OSCILLOSCOPE. A 200 kHz bandwidth oscilloscope having a maximum sensitivity of 10 mV/division gives a maximum viewing sensitivity of 0.1 dB/division which would be adequate for any application. Isolated and differential inputs on both axis simplify grounding problems since isolating the oscilloscope input avoids a signal ground connection at the oscilloscope.

b. DB AND DB-NULL MODES. In the DB mode, the digital display indicates power level change from the reference level in single frequency operation. In swept operation the digital display reading is confusing since it measures a continually varying voltage. In the DB mode, power deviations from the reference level are indicated directly on the oscilloscope screen and the display gives a presentation of this device performance. Detailed examination may be implemented as follows:

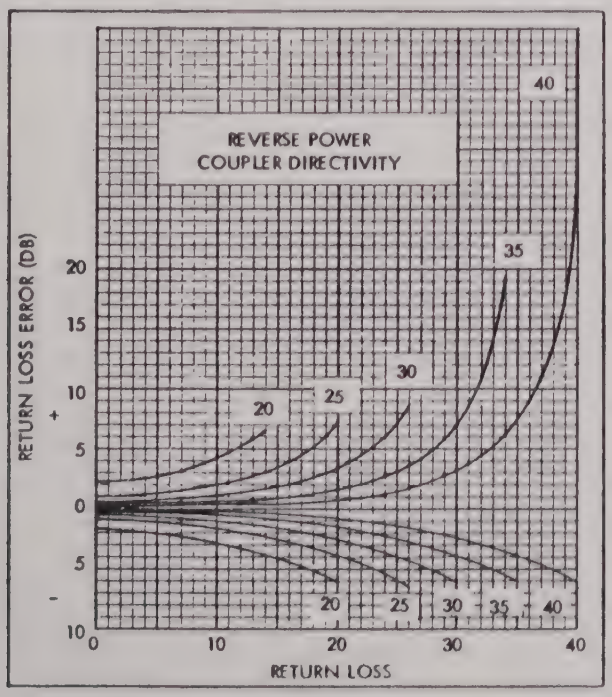
The best way to measure a particular power level in the DB mode is to switch to the frequency of input and read the level indicated on the digital display. In the DB-NULL mode the waveform may be centered on the oscilloscope face at virtually any sensitivity for viewing at maximum resolution. Figure 5-3 shows the advantage of the DB-NULL mode when a swept waveform is to be viewed at maximum resolution. The relative power at any point in the waveform is measured by placing that point on the horizontal center line of the oscilloscope screen using the OFFSET control (note: the oscilloscope must be vertically balanced such that the horizontal center line represents 0 V). The value of the injected offset is then indicated on the digital display. If many points are to be measured and the sweeper may be easily set to the desired frequency by switches or push buttons, then single frequency measurements in the DB mode are quicker and more convenient since the nulling process is eliminated.

c. ZEROING. For wide band sweeps in the microwave region, lack of coupler tracking, slight frequency sensitive variations in the detectors, and cables used in the test setup cause the calibration (0 dB) reference line to deviate from a straight line. Normally this deviation is slight, but if it is large enough to add unacceptable error, then it should be recorded and accounted for.



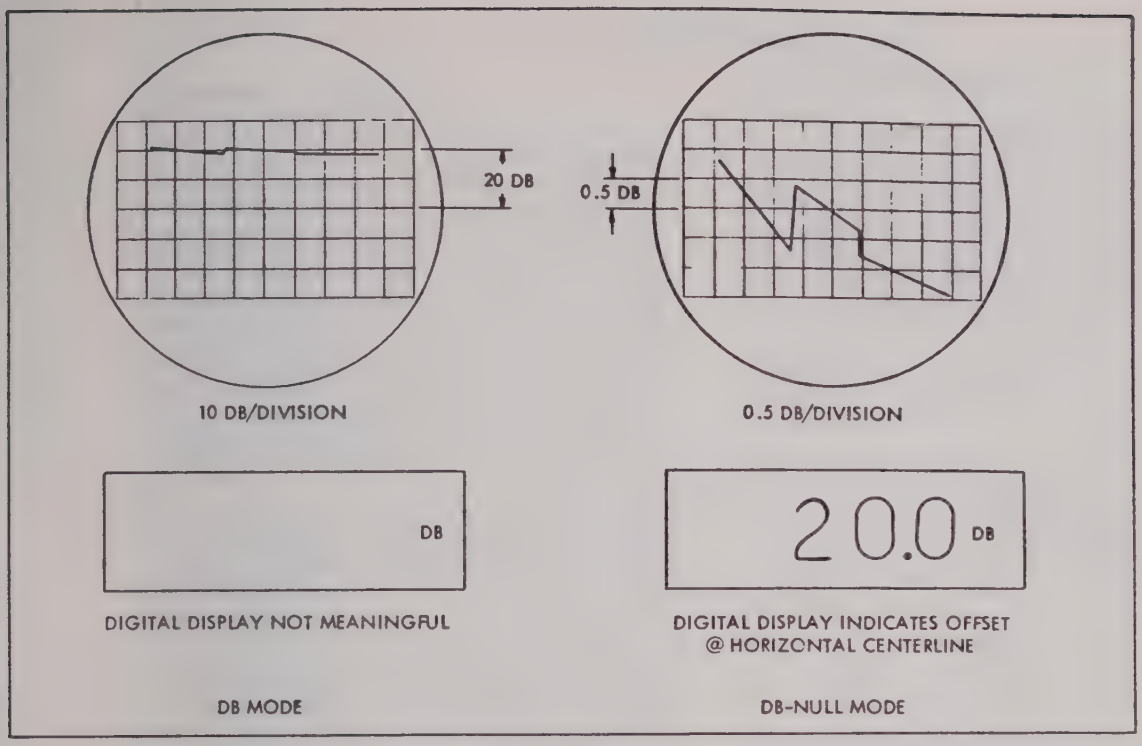
TYPICAL CONNECTIONS FOR SWEPT REFLECTOMETER MEASUREMENT SYSTEM

FIGURE 5-1



RETURN LOSS ERROR VS RETURN LOSS

FIGURE 5-2



DB AND DB-NULL MODES
DURING SWEPT OPERATIONS

FIGURE 5-3

SECTION 6
CIRCUIT DESCRIPTION

6.1 GENERAL DESCRIPTION.

Simplified circuit diagrams of the Model 1009 are shown in Figures 6-1 and 6-2. Referring to Figure 6-1, the detector output, E_{dc}, is fed through R_D to the current summing junction of the input amplifier. E_{dc} is also applied to the compensation circuitry through the thermistor and a 470 k ohm resistor. The compensation circuit output current is fed into the current summing junction of the input amplifier such that the total current into the input amplifier is $I_{dc} + I_{comp}$. The feedback around the input amplifier determines whether the Model 1009 is operated in the logarithmic or linear mode. When operated in the logarithmic mode, a transistor is used in the feedback loop. The output voltage of this amplifier is equal to the log of the input current. In the linear mode, a resistive divider is placed across the input amplifier. This divider is represented schematically by a variable resistor in Figure 6-1.

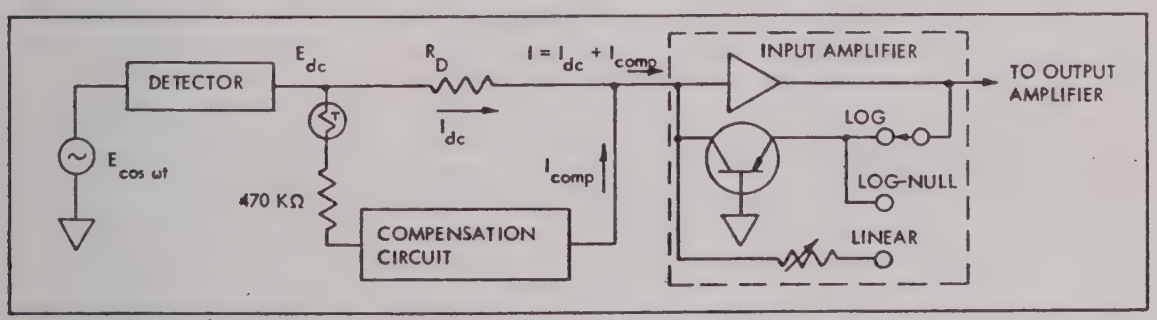
Figure 6-2 shows the output amplifier, digital display, and a simplified schematic of the output switching. The first stage of the output amplifier is used to amplify the logarithmic output of the input amplifier. All logarithmic offsets are summed by the second stage and applied to the output switching circuitry. Note the output amplifier is used only in the logarithmic mode. In the linear operating mode, the output of the input amplifier is applied directly to the output jack and to the digital display. In the log-null mode (DB-NULL), the digital display is connected to measure the calibrated offset injected into the second stage of the output amplifier.

6.2 DETECTOR COMPENSATION.

Crystal diode detectors have been used to measure RF power for quite some time, but until recently their useful measurement range has been restricted to the square law region where output voltage is approximately proportional to input power. In reasonably fast-response applications, the lower end of the measurements range is limited by noise and is about -40 dBm. The upper end of the usual measurement range occurs at about -10 dBm where the detector output response begins to depart significantly from square law. In the Model 1009, a compensation signal is generated such that when it is added to the detector output, the resulting sum is proportional to RF power input to levels beyond +10 dBm. This is possible because of the predictable behavior of the diodes used in crystal type detectors.

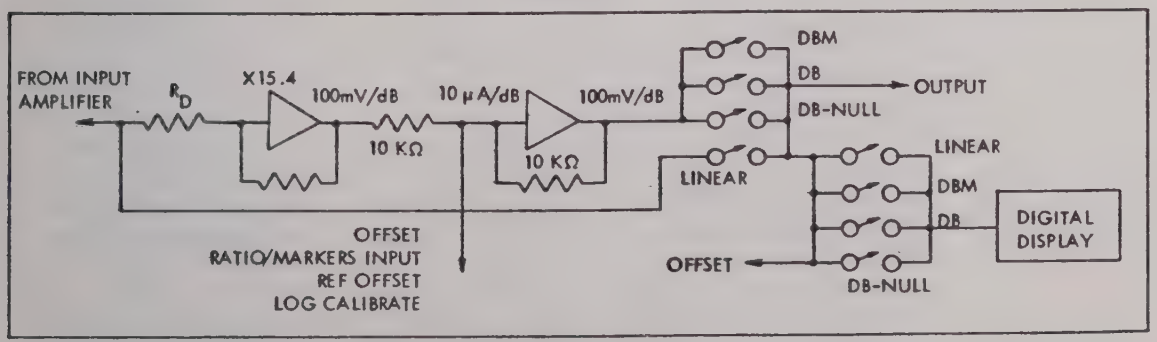
Figure 6-3 shows the schematic of a typical crystal detector. The crystal diode, CR1, merely rectifies the RF voltage across the terminating resistor, R_t. In the Model 1009, R_t is a 50 ohm termination and CR1 is a microwave point contact diode. The relationship between the peak RF input voltage, E, and the detectors dc output, E_{dc}, is described by the following equation:

$$\left[1 + \left(\frac{R_V}{R_L}\right) \alpha E_{dc}\right] e^{\alpha E_{dc}} = I_o(\alpha E) \qquad \text{Eq. (1)}$$



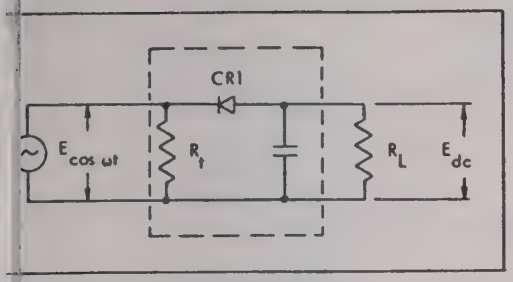
COMPENSATION AND INPUT AMPLIFIER

FIGURE 6-1



OUTPUT AMPLIFIER AND
OUTPUT SWITCHING

FIGURE 6-2



DETECTOR

FIGURE 6-3

re: R_V is the diode low level video resistance

R_L is the detector load resistance

α is proportional to Q/kt

I_o is the zero order modified Bessel function of the first kind.

w –20 dBm, Equation (1) may be approximated by the ession.

$$E_{dc} = \frac{\alpha E^2}{4(1+k)} \qquad \text{Eq. (2)}$$

re: k is R_V/R_L.

square law relationship shown in Equation (2) shows that detector dc output is proportional to the square of RF in- voltage which in turn is proportional to the RF input er. Equation (2) describes the desired detector response le Equation (1) describes the actual detector response. compensation circuitry in the Model 1009 generates a al equal to the difference between the detector outputs ribed by Equation (2) and Equation (1). The resulting pensation signal is added to the detector output described quation (1) and the resultant sum of signals provides a re- se described by Equation (2). This compensation is ef- ive to power levels greater than +10 dBm. This compensa- is temperature sensitive due to the fact that the detector le parameters are temperature dependent. However, the perature dependence of the diode parameters is predict- so that a thermistor network may be used to maintain urate compensation over a temperature range of 18°C to C. It should be noted at this point that the thermistor work maintains the compensation accurate for relative, er than absolute, power measurements over the tempera- range. By proper design, this temperature dependence been minimized in the Model 1009. Furthermore, the rument is equipped with a calibrator so that accurate ab- te power measurements are easily made at any temperature ween 18°C and 45°C. Several design considerations indi- e that k, as described in Equation (2), be equal to 0.5 25°C. In other words, the load resistance, R_L, as indi- ed in Figure 6-3 should be equal to twice the low level eo impedance of the detector diode. It is well to point that R_L in Figure 6-3 consists of two components, one ng on external load resistor, and the other a parasitic ading resistance inherent in the detector diode. Thus, sum of the diode spreading resistance R_s, and the exter- load resistor must be twice as large as the diode low level eo impedance, R_V. R_s is merely the output resistance of detector measured at high level (+10 dBm). The output stance of the detector at low level (-30 dBm) is equal to sum of $R_s + R_V$. Since R_V varies considerably from diode to diode, the external detector load resistor is different for each Model 1009. Referring to Figure 6-1, this external detector load resistor consists of R_V in parallel with the series combination of the thermistor and the 470 Kohm resistor in the compensation amplifier input. Since the thermistor resistance is considerably smaller than the 470 Kohm resistor, the external load is essentially R_D in parallel with 470 k ohm. Thus, R_D, the detector load resistor which varies from instrument to instrument, is described by the following relationship:

$$\frac{(R_D)(470\text{ k})}{470\text{ k} + R_D} + R_s = R_V \qquad \text{Eq. (3)}$$

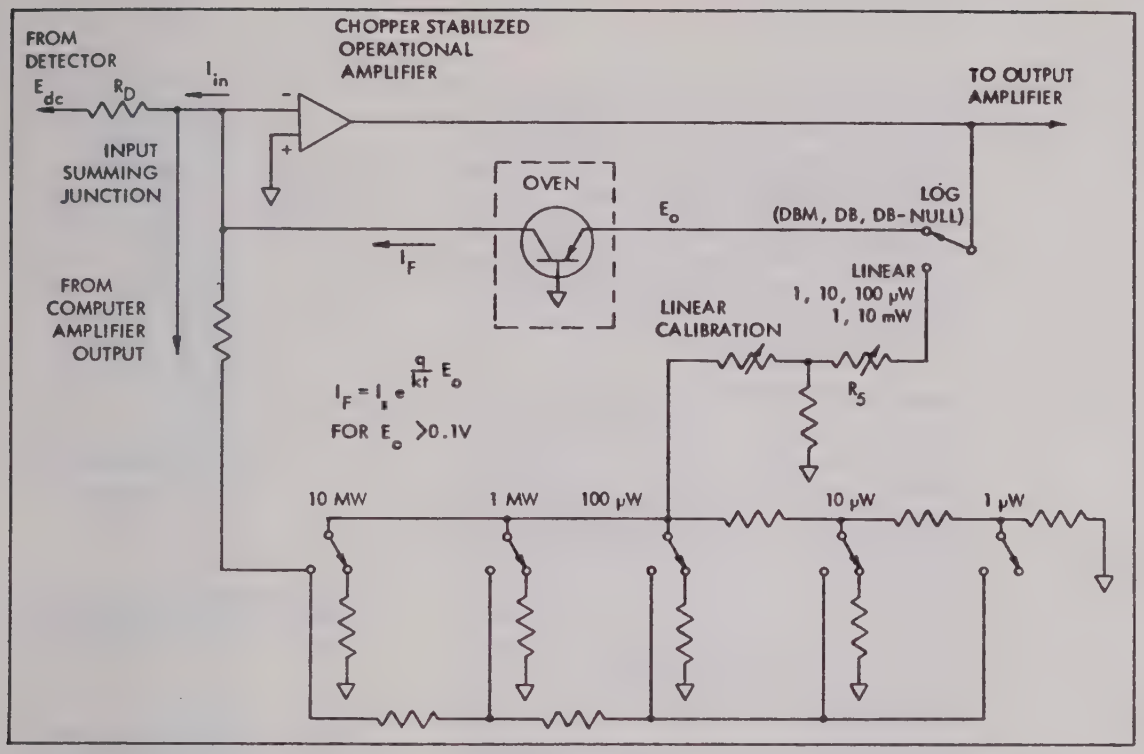
6.3 INPUT AMPLIFIER.

A simplified circuit diagram of the input amplifier is shown in Figure 6-4. This amplifier consists of a high gain, chopper stabilized, operational amplifier capable of being operated in logarithmic or linear mode by selection of its feedback network. For reasons discussed in Section 6.2, the input resistor, R_D, shown in Figure 6-4, is factory selected and is a function of the detector used.

To operate the input amplifier in the logarithmic mode, a transistor is used in the feedback loop around the operational amplifier. Referring to Figure 6-4, I_{in} is proportional to $e^{qE_o/kt}$ since the operational amplifier has very high gain. Thus, E_o is proportional to log I_{in}. This logarithmic relationship between I_{in} and E_o holds over many decades of current because parasitic collector currents in the logging transistor are eliminated by operating its collector base junction at zero volts. When operated in the logarithmic mode, the output level of this amplifier is approximately 6.4 mV/dB and is a function of the temperature of the logging transistor. To maintain the logarithmic coefficient independent of ambient temperature, the logging transistor is mounted in a temperature controlled oven and held at 60°C. The oven control circuit which maintains the oven at a constant temperature is shown schematically in Figure 6-5. A power transistor serves to heat the oven and a thermistor mounted in the oven senses temperature. A simple one-stage amplifier is connected between the thermistor and the transistor heater amplifier. When the oven is at its correct temperature, the driver amplifier input is very near zero volts and the transistor heater amplifier generates just enough heat to maintain the oven at its proper temperature.

The chopper-stabilized operational amplifier is a high gain unit that is essentially free from dc drift. The action of the chopper amplifier is to hold the input summing junction of the operational amplifier at zero volts.

In the linear mode, the operational amplifier is controlled by a resistive feedback attenuator. Variable resistor, R5, in Figure 6-4 adjusts the gain of the input amplifier to match it to the detector being used. R5 is a factory selected value. The linear calibration adjustment is a front panel, screwdriver control used to adjust the input amplifier gain over a limited range to accommodate the slight variations in detector output caused by ambient temperature changes. In the linear mode, the input amplifier has 5 gain settings which correspond to 1 μW, 10 μW, 100 μW, 1 mW, and 10 mW full scale ranges. Referring to Figure 6-4, the feedback attenuator is essentially a ladder type. Since the impedance driving the feedback attenuator is neither low nor constant, the attenuator must present a constant impedance to the linear calibration potentiometer.



INPUT AMPLIFIER

FIGURE 6-4

6.4 COMPUTER AMPLIFIER.

Figure 6-6 is a simplified circuit diagram of the computer amplifier. Input is from the detector output. The first stage logs the detector output and adjusts the level at which compensation becomes significant. The second stage of amplification is used to adjust the level of compensation. Second stage output is fed to an anti-log transistor whose collector delivers the compensation current to the input amplifier input summing junction.

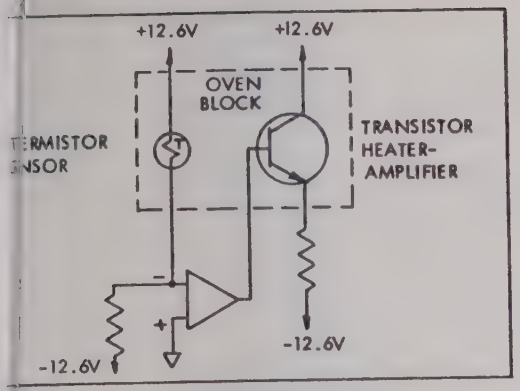
E_{dc} is applied to the logging stage of the computer amplifier through a thermistor and a 470 k ohm resistor. The thermistor changes the correction signal such that level compensation is independent of temperature from 18°C to 45°C. E_{dc} is logged in the computer amplifier in precisely the same manner as it is logged in the input amplifier. Because of its temperature sensitivity, the logging transistor in the computer amplifier is also placed in the oven to keep the logging sensitivity of this amplifier independent of temperature. Since the correction signal does not become significant until detected RF power levels are above -20 dBm, the computer logging amplifier need not be as stable as the input logging amplifier. As a consequence, this amplifier is not chopper stabilized. The X1.9 amplifier drives the anti-logging transistor which sets the compensation for the particular detector by adding a signal to the input of the input amplifier. As in the case of the logging transistor, the anti-logging transistor is temperature sensitive and is also placed in the temperature controlled oven.

6.5 OUTPUT AMPLIFIER.

A simplified circuit diagram of the output amplifier is shown in Figure 6-2. The output amplifier consists of two stages and is used only in the logarithmic modes. The first stage multiplies the log signal from the input amplifier by 15.4 to give a log sensitivity of approximately 100 mV/dB on its output. This signal is applied to the current summing junction of the input amplifier second stage. The sensitivity of this current summing junction is 10 μ A/dB. NULL OFFSET, log calibration, REF OFFSET, and RATIO/MARKERS signals are also applied to the summing junction. The second stage amplifier converts its current input to a voltage resulting in an output level of 100 mV/dB which is applied to the OUTPUT jack and to the digital display.

The NULL OFFSET and REF OFFSET input signal are controlled from the front panel by the OFFSET knob. The front panel OFFSET selector lever determines which signal the OFFSET knob controls. The REF OFFSET signal is applied to the output amplifier current summing junction in the DB and DB-NULL operating modes. The REF OFFSET control is used to adjust the OUTPUT voltage to 0 when the detector RF power INPUT is at a reference or 0 dB level. The OFFSET control is active only in the DB-NULL mode and is primarily useful for making measurements on swept displays. In the DB-NULL mode, the OFFSET is indicated on the digital display. The log calibrate (0 DBM) adjustment is a front panel screwdriver control which is used when making absolute power measurements in the logarithmic mode. This adjustment is used to adjust the digital display to read 00.0 DBM when 0 dBm (1 mW) is being put into the detector RF INPUT by means of the CALIBRATOR.

The RATIO/MARKERS INPUT is connected to the output amplifier current summing junction in the DB and DB-NULL operating modes. This input is useful for injecting video markers into a swept display or where it is desired to ratio two signals by summing their logs. Positive going signals at this



OVEN CONTROLLER

FIGURE 6-5

but will cause a negative going OUTPUT signal. The sensitivity of this input is such that no adjustments are required when two Model 1009 units are used to ratio two signals.

6 CALIBRATOR.

Figure 6-7 is a circuit diagram of the RF level calibrator. The calibrator consists of a 30 MHz oscillator and a 20 dB, 50 ohm attenuator. CALIBRATOR OUTPUT is from a front panel threadless Type N connector.

The 30 MHz calibrator oscillator is operated within a very stable amplitude regulating loop so that its output level is only a function of a reference voltage. The calibrator output level is set by adjusting the reference voltage divider. The oscillator output is fed to the calibrator switch from a 50 ohm resistor tapped into the 30 MHz resonant circuit. In the first position, the calibrator switch de-energizes the calibrator oscillator. In the second position, the calibrator oscillator is energized and connected to the calibrator output through a 20 dB, 50 ohm attenuator. Finally, in the third position, the calibrator oscillator is energized and connected directly to the calibrator output to give a 0 dBm (1 mW) output.

6.7 DIGITAL DISPLAY.

6.7.1 GENERAL DESCRIPTION. The Pacific Measurements Digital Display is used to convert the analog signals developed by the instrument into digital form for direct readout using gas filled display tubes. In addition, it generates Binary Coded Decimal (BCD) signals which can be used with data acquisition systems.

In order to provide high speed, excellent long term stability and to make use of readily available, off-the-shelf integrated circuits, the digital display uses a successive approximation process in order to generate a display. The logic functions of the instrument are performed by integrated circuits. The actual process of approximation is done by transistor switches controlling high stability, precision resistors. Specialized integrated circuits are used to drive the display tube numerical indicators.

For descriptive purposes, the digital display unit can be broken down into four elements. The first, and fundamental, element is the reference supply which forms the standard for comparison against which all input voltages are measured. The second is the approximation circuit which generates the current to balance the current developed by the input voltage applied across the input resistor. The third is the comparator which generates the control signals to be applied to the approximation circuit. The fourth part of the system can be described broadly as the logic circuitry which provides the control information to permit the approximation process to proceed in an orderly, sequential fashion. In principle, the process of successive approximation is merely an automatic way of doing what an operator of a differential voltmeter does by hand. The user of a differential voltmeter measures an input voltage by obtaining an approximate null; setting the most significant digit on the instrument first and then progressively refining the approximation by setting successively less significant digits, until all available digits have been set.

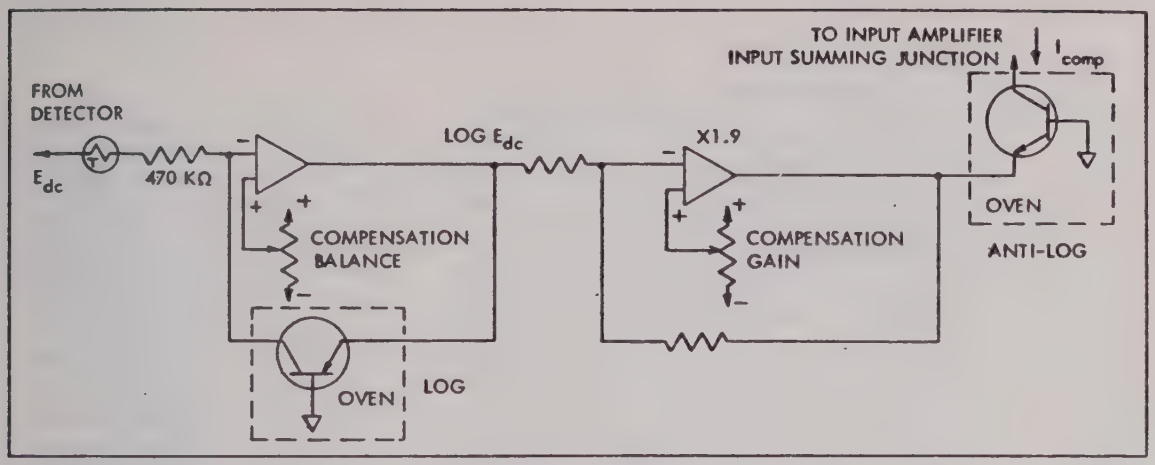
In the Pacific Measurements Digital Display, the process of approximation is carried out in a BCD sequence, that is, all the numbers from zero through nine are derived by adding the Binary numbers 0 1 2 4 8 to form each decade. In order to form three decades, twelve non-zero numbers are required. Since the Pacific Measurements Digital Display also has the capability of displaying the overrange 1, an additional number is required for a total of 13. The approximation circuit consists of 13 solid state switches connected to 13 precision resistors. If a switch is actuated, it will connect one end of the resistor to a precise reference voltage. The opposite end of each resistor is tied to a common point together with a precision resistor leading to an input voltage. In addition, a high gain, integrated circuit differential amplifier monitors this point to serve as a null detector, or comparator.

The approximation process is performed under control of the logic circuit, so that the resistor corresponding to the most significant Binary digit is selected first, then the next significant digit and so on until the least significant digit has been determined. By proceeding in this fashion, advantage may be taken of the fact that each binary digit which is not in excess of the input is required in the answer. Thus, the logic circuits first connect a given resistor to the reference supply, the comparator determines whether the current through the resistor is greater or less than that required to produce a null. If it is greater, the logic disconnects the resistor; if it is less, the resistor remains connected. At the end of the approximation process, resistors are connected between the null point and the reference supply to correspond to BCD numbers equal to the input voltage. The control voltages applied to the switches are also the BCD output, and they are decoded into decimal form to drive the display tubes.

Since the approximation process operates in one direction only, the instrument will accept signals of only one polarity at its input. In order to permit measurements of signals of both polarities and to isolate the rest of the instrument from noise generated in the digitizing process, an "absolute value circuit" is included in the system. If a negative input is applied to the instrument, the input resistor is connected through a non-inverting amplifier to the voltage to be measured. If a positive voltage is applied to the input, the input resistor is connected through both the inverting and non-inverting amplifiers to the input voltage.

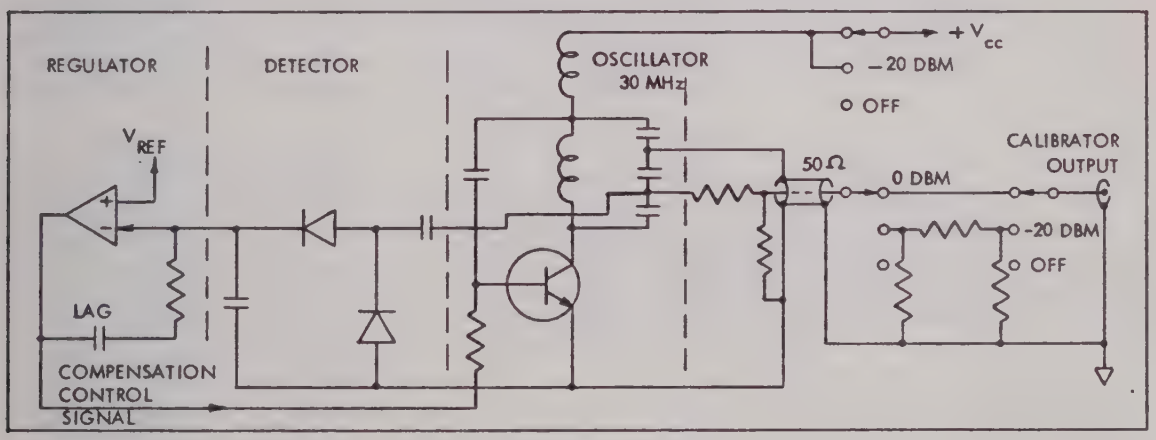
6.7.2 REFERENCE SUPPLY.

Refer to the circuit diagram 10843, sheet 1, in Section 8. The reference supply is a high gain dc amplifier. The input stage of the amplifier is a temperature stable silicon dual NPN transistor. On the input side of the amplifier is the



COMPUTER AMPLIFIER

FIGURE 6-6



CALIBRATOR

FIGURE 6-7

voltage reference consisting of the temperature stable Zener diode (CR8) and a resistive divider network. R82 through R84 are resistors which may be selectively shorted out in order to center the potentiometer (R87) to obtain precisely 4 V at the input of the amplifier. This permits the potentiometer to have small range so that the reference may be set to within 1 mV. The output voltage of the power supply is fed for comparison against the reference. A condenser, C8, stabilizes the power supply and provides a low impedance at high frequencies. In order to insure long term stability, the Zener diode is aged for several days prior to installation. If a replacement Zener is installed, the output voltage of the power supply should be checked and reset, if necessary, after a few days of operation as there is appreciable voltage change across a Zener diode during its first few hours of operation after which further voltage changes are slight and occur at a very slow rate.

6.7.3 APPROXIMATION CIRCUIT.

The approximation circuit consists of silicon PNP transistors operated as switches and driven from the logic circuitry. In order to minimize the voltage drop across the transistors when they are conducting, transistors corresponding to the eight most significant Binary digits are connected so that the collector serves as the emitter in the ON state. Furthermore, for the four most significant digits, a two stage switch is used with a second transistor supplying most of the current to the summing resistor. The primary switch transistor will then have little current flowing through it, thus a very small voltage drop will develop across its parasitic resistances. Each transistor switch is driven from an NPN transistor referenced to ground whose base is supplied with a signal from the logic circuitry. Resistors of very high precision are used in the most significant digits. Digits of less significance make use of resistors of somewhat less precise value.

6.7.4 COMPARATOR.

A high gain, integrated circuit differential amplifier monitors the summing junction of the approximation circuit. The amplifier is connected so that it inverts the input signal. Since the input to the instrument must always be negative and the feedback signal from the approximation signal is positive, the comparator will have a negative output voltage if the current supplied by the approximation circuit is larger than the input current, and a positive output voltage if the current supplied by the approximation circuit is less than the input current.

6.7.5 LOGIC

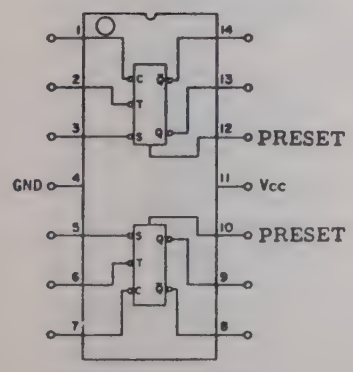
By far the most complex portion of the logic circuitry is concerned with the commutation process. In order for the process of successive approximation to proceed in an orderly fashion, it is necessary for the logic circuits to generate control signals which successively connect to the reference voltage resistors corresponding to the most significant digit down through the least significant. Actually, this process must be repeated twice for each resistor. That is, each resistor must be connected to the reference voltage and a short time later disconnected if it is not required in the approximation. Each solid state switch is connected to the output of a JK flip-flop. The flip-flop performs two functions. First, it transfers information placed at its input to its output during, but only during, a negative transition of the clock fed to its timing input. Second, it will store information until new data is fed to it and it receives an additional clock pulse. This permits all of the set and clear inputs to the JK flip-flops in the storage section to be connected in parallel. Thus, a command to close the solid state switch may be fed to all flip-flops but only one receiving a clock pulse will respond to it. Likewise, a command to disconnect may also be fed to all of the flip-flops without affecting any but the desired one. Thus, much of the circuitry is concerned with generating pairs of pulses which occur at progressively later times during the measurement cycle.

A multivibrator serves as a clock operating at approximately 75 kHz. The output of the clock is fed into a succession of five flip-flops which divide by 32; at the end of the 32nd pulse the last flip-flop overspills, triggering a sixth flip-flop which terminates the process. A succession of AND gates and inverters are connected to the complementary outputs of the four flip-flops following the first one to provide 13 separate successive outputs, each with just one pulse occurring during the process. These are combined with the clock pulses to produce 13 separate signals each consisting of a pair of clock pulses occurring at progressively later times during the measurement cycle. These clock pulses are fed to JK flip-flops controlling the solid state switches in the approximation circuit.

During the negative transition of the first clock pulse of each pair, a signal is applied to the input of all JK flip-flops in the storage section of the unit such as to produce a switch closure. However, only one of the flip-flops is receiving a clock pulse at that time and, consequently, only one switch closes. During the second clock pulse a signal derived from the comparator is applied to the input of all JK flip-flops which causes the resistor to be disconnected during the next clock pulse if the output of the comparator is negative. If the output of the comparator is positive, this signal does not appear and the resistor remains connected. This process starts with the resistor corresponding to the over-range "1" digit and ends with the resistor corresponding to 1 in the last column. The instrument then remains dormant until a new measurement command arrives. The measurement command is a pulse applied to the preset terminals of all flip-flops which resets them to their zero state, permitting the count-down process to begin again. A one-shot multivibrator generates this pulse. A Schmitt trigger drives the one-shot multivibrator. In order to permit the system to free run, the output of the Schmitt trigger also is fed to a capacitor and from the capacitor back to the input of the Schmitt. The capacitor alternately charges and discharges between hysteresis limits of the Schmitt permitting continuous free running operation. Alternatively, the Schmitt may be triggered from an external signal source at frequencies up to 1 kHz.

6.7.6 INTEGRATED CIRCUITS.

A variety of integrated circuits are used in this instrument. They are standard RTL circuits. Circuit diagrams are shown in Figure 6-8 and Figure 6-9 for your reference. Additional information regarding them is available from the manufacturer. The type numbers shown are manufacturers numbers. Individual instruments may have devices of other manufacturers installed and the type numbers may not agree with those shown.



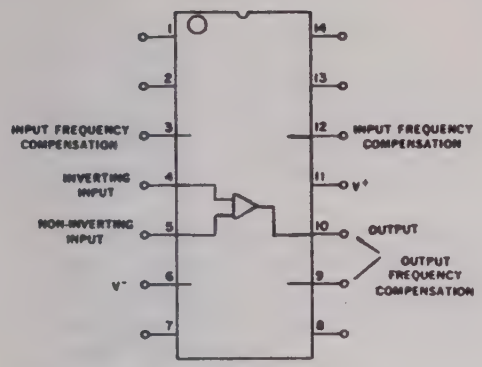
MC790P — Dual J-K Flip-Flop

Truth Table

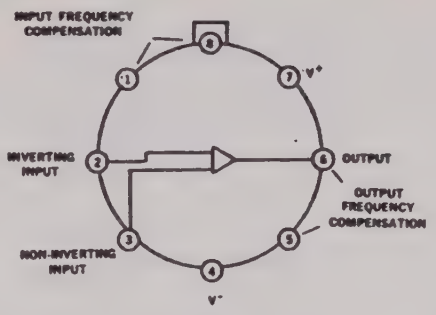
Clock T	Set S	Clear C	T=n+1 Q
0	Lo	Lo	$\overline{Q^n}$
0	Lo	Hi	Lo
0	Hi	Lo	Hi
0	Hi	Hi	Q^n

INTEGRATED CIRCUIT

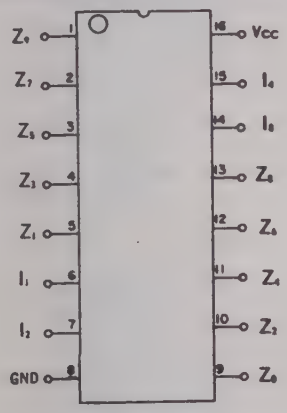
FIGURE 6-8



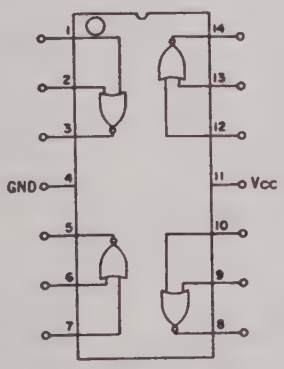
MC1709C Operational Amplifier



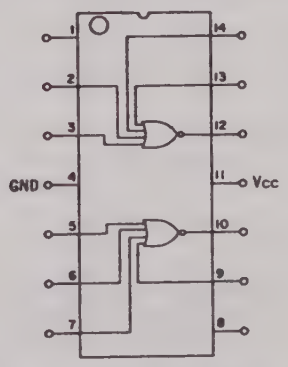
MC1709 C Operational Amplifier



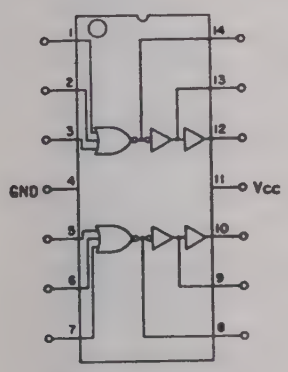
CμL 9960 Decoder/Driver



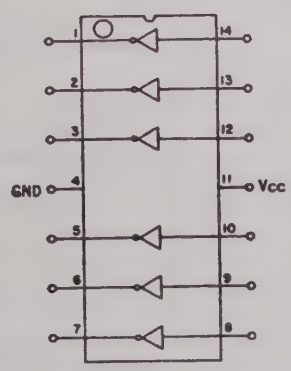
MC724P — Quad 2-Input Gate



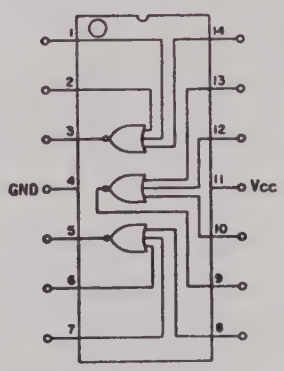
MC725P — Dual 4-Input Gate



MC788P — Dual Buffer



MC789P — Hex Inverter



MC792P — Triple 3-Input Gate

INTEGRATED CIRCUITS

FIGURE 6-9

SECTION 7
MAINTENANCE

7.1 PERIODIC MAINTENANCE

The following maintenance should be performed once a year unless the instrument is operated in an extremely dusty or chemically contaminated environment or is subjected to severe abuse. In such cases, more frequent maintenance is indicated.

a. Blow out all accumulated dust with forced air under moderate pressure. Be particularly careful to clean the area in the vicinity of the approximation resistors of the digital display. Any scum or grime in this region may have to be removed with a suitable solvent specified for this purpose.

b. Inspect the instrument for loose wires and damaged components. Check to see that all plug-in PC boards are properly seated in their connectors.

c. Make a performance check in accordance with the procedure of Section 4, "Performance Checks."

7.2 INTERNAL ADJUSTMENTS AND TEST POINTS.

Under normal conditions none of the internal adjustments should need adjusting except after a repair of a failure.

CAUTION

Do not attempt to make any ajustments on this instrument until you have read the following section completely. Some adjustments interact and must be made in the proper sequence or the instrument will not perform properly. Many of the voltages to be measured are not with respect to ground; therefore, a voltmeter with a floating input must be used.

7.2.1 DESCRIPTION OF ADJUSTMENTS.

The function of each adjustment is described below. Refer to Figure 7-2 for the location of each adjustment.

a. R5, 1 MW SET. Used to set the linear gain of the input amplifier to the value required by the sensitivity of the detector used. R5 is a factory selected value.

b. R13, -20 DBM CAL SET. Used to set the calibrator to 10 μW into 50 ohm.

c. A1R9, +12.6 V POWER SUPPLY CALIBRATION ADJUSTMENT. Used to set this positive power supply to +12.6 V ± 10 mV.

d. A1R18, -12.6 V POWER SUPPLY CALIBRATION ADJUSTMENT. Used to set this negative power supply to -12.6 V ± 10 mV.

NOTE: The -12.6 V power supply must be set before the +12.6 V power supply calibration adjustment is adjusted.

e. A2R3, ZERO SET. Used to set the display to zero for zero input voltage.

f. A2R87, +4.000 V ADJUSTMENT. Used to set the reference supply to +4.000 V ± 1 mV.

g. A3R2, NEGATIVE INPUT AMPLIFIER BALANCE ADJUSTMENT. Used to adjust the negative input amplifier to have zero output from zero input.

h. A3R11, POSITIVE AMPLIFIER BALANCE ADJUSTMENT. Used to adjust the positive amplifier for zero output with zero volts input.

i. A4R10, COMPENSATION BALANCE. Used to balance the computer log amplifier.

j. A4R26, FINE COMPENSATION GAIN ADJUSTMENT. Used to set the detector compensation level.

k. A4R28, COARSE COMPENSATION GAIN ADJUSTMENT. Used to set the detector compensation level.

l. A4R56, INPUT CURRENT BALANCE ADJUSTMENT. Used to compensate for leakage current in the input amplifier input transistor.

m. A4R89, LOGARITHMIC GAIN ADJUSTMENT. Used to set the level of log signal into the output amplifier current summing junction at 10 μA/dB.

n. A4R95, OUTPUT GAIN ADJUSTMENT. Used to set output level to 100 mV/dB.

o. A4R151, RATIO/MARKERS INPUT SENSITIVITY ADJUSTMENT. Used to set the sensitivity of the RATIO/MARKER INPUT to 100 mV/dB.

p. A4R168, OUTPUT AMPLIFIER BALANCE ADJUSTMENT. Used to set output amplifier summing junction to zero volts.

q. A4R175, 1 μW ZERO ADJUSTMENT. Used to make the zero condition the same for both logarithmic and linear modes.

r. A4R177, CHOPPER ZERO ADJUSTMENT. Used to set the voltage at the chopper input to zero volts.

s. A6R12, 0 DBM CAL SET. Used to set the calibrator oscillator output to 1 mW into 50 ohms.

7.2.2 TEST POINTS.

Refer to Figure 7-2 for location of the test points.

a. TP1 (A1J1), +12.6V. Measure between +TP1 and floating ground, -TP2. +12.6 V ± 10 mV, ripple less than 0.5 mV peak to peak at 115 V ac line.

b. TP2 (A1J2), FLOATING GROUND.

c. TP3 (A1J3), -12.6 V. Measure between -TP3 and floating ground, +TP2. -12.6 V ± 10 mV, ripple less than 0.5 mV peak to peak at 115 ac line.

d. TP4 (A1), AUXILIARY POWER SUPPLY. Measure between +TP4 and +12.6 V, -TP1. 4.5 ± 1.0 V, ripple less than 50 mV peak to peak at 115 V ac line.

e. TP5 (A1), PRIMARY REFERENCE VOLTAGE. Measure between +TP5 and floating ground, -TP2, 5.9 V to 6.5 V.

f. TP9 (A4J11), OUTPUT AMPLIFIER SUMMING JUNCTION. Measure between TP9 and TP20. Set A4R168 for zero volts.

g. TP11 (A4J1), COMPUTER LOG AMPLIFIER OUTPUT. Measure between +TP11 and floating ground, -TP2. A decade change in the detector output voltage (measure between +TP18 and signal ground, -TP20), should cause 64 mV change at TP11.

h. TP12 (A4J2), COMPUTER X1.9 AMPLIFIER OUTPUT. Measure between +TP12 and floating ground, -TP2.

A voltage change on TP12 should be 1.9 times the voltage change on TP11.

i. TP13 (A4J3), OVEN HEATER CURRENT. Measure between +TP13 and -12.6 V, -TP3. Voltage should be approximately 2.0 V immediately after turn on and settle to less than 0.6 V within 5 minutes.

j. TP14 (A4J4), CHOPPER DEMODULATOR OUTPUT. Measure between TP14 and floating ground, TP2, using an oscilloscope. At the time the demodulator switch is closed, the voltage waveform should be a clean 0 V. When the demodulator is open, noise should be present, magnitude approximately 0.05 V peak to peak.

k. TP15 (A4J5), INPUT AMPLIFIER OUTPUT. Measure between +TP15 and floating ground, -TP2. When the Model 1009 is operating in the linear mode, this voltage should be 5 V for full scale deflection. In the log mode, a 10 dB change in detector input power should result in a 64 mV voltage change at this point.

l. TP16 (A4J6), X15.4 AMPLIFIER OUTPUT. Measure between +TP16 and floating ground, -TP2. The voltage gain from TP15 to this point should be 15.4 ± 2%.

m. TP18 (A4J8), DETECTOR OUTPUT. Measure between -TP18 and signal ground +TP20. This voltage should be at least 0.2 mV for 1 μW (-30 dBm) of detector RF input.

n. TP19 (A4J9) CHOPPER INPUT. Measure between TP19 and TP20. Set A4R177 for zero volts.

o. TP20 (A4J10) SIGNAL GROUND.

p. TP21 (A2J1) DIGITAL DISPLAY INPUT.

q. TP22 (A2J2) DIGITAL DISPLAY GROUND.

r. TP23 (A2J3), +3.6 V. Measure between TP23 and TP22 +3.6 V ± 100 mV.

s. TP24 (A2J4), +4.000 V. Measure between TP24 and TP22. +4.000 ± 1 mV. Ripple less than 0.5 mV peak to peak at 115 V ac line.

t. TP25 (A2J5) CLEAR LINE. Used to provide the trigger source for an oscilloscope when checking logic circuitry. Also indicates the proper operation of the frequency divider.

u. TP26 (A2J6), PRESET LINE. Used to check for proper operation of the preset one-shot multivibrator.

v. TP27 (A2J7), SET LINE. Used to check for proper operation of the comparator.

7.3 CALIBRATION.

7.3.1 EQUIPMENT REQUIRED.

To calibrate the Model 1009, the following equipment is required.

a. A differential or digital voltmeter with 100 μV resolution and 0.01% accuracy.

b. A power signal source having a frequency between 25 MHz and 35 MHz with 10 mW power output. Output power must be adjustable so that an output of 10 mW ±10μW can be obtained. It must have a source SWR less than 1.05 and a maximum harmonic level of -50 dB.

c. A step attenuator having a 0 to 50 dB insertion loss range and calibrated to 0.02 dB at the frequency of the signal source.

d. A precision power supply capable of supplying ± 0 to 4 V into 4 k ohm with 100 μV resolution.

7.3.2 CALIBRATION PROCEDURE.

The following steps must be performed in the order indicated.

a. Adjust the -12.6 V power supply. Adjust the voltage between +TP2 (A1J2) and -TP3 (A1J3) with A1R18 to be -12.6 V ± 10 mV.

b. Adjust the +12.6 V power supply. Adjust the voltage between +TP1 (A1J1) and -TP2 (A1J2) with A1R9 to be +12.6 V ± 10 mV.

c. Check +3.6 V supply. Measure between +TP23 (A2J3) and -TP22 (A2J2), +3.6 V ± 200 mV.

d. Adjust the +4.000 V supply. Adjust the voltage between +TP24 (A2J4) and -TP22 (A2J2) with A2R87 to be +4.000 V ± 1 mV.

e. Adjust the digital display to zero. Disconnect the output of the input amplifier board by removing the lead from Terminal 15 (A2).

CAUTION

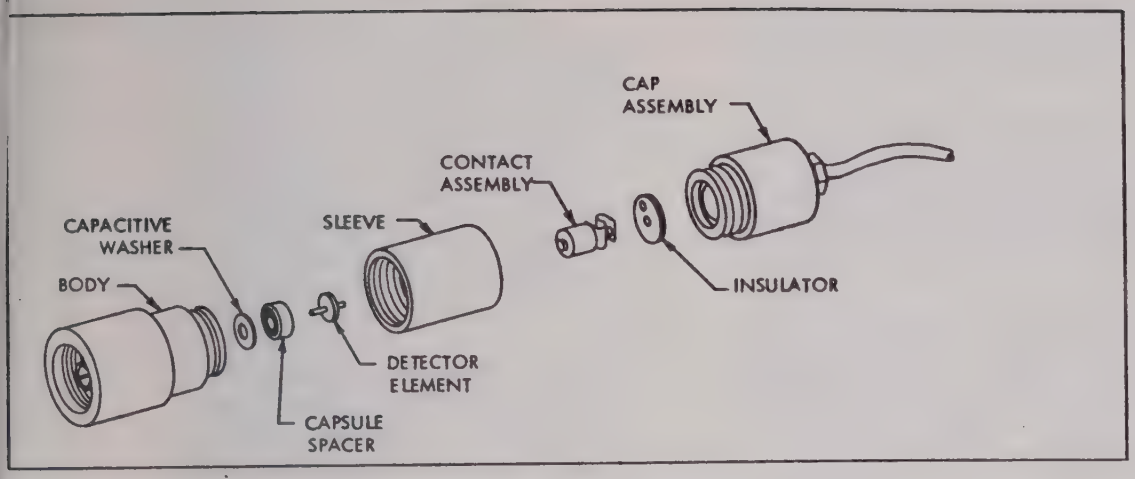
Be very careful to grasp the metal portion of the jack with a pair of pliers. Do not pull on the wire.

Connect the positive side of the precision power supply to TP22 (A2J2) and the negative side to Terminal 15 (A2). Adjust A2R3 until transition from zero to 1 occurs between 1.5 and 2.5 mV. Disconnect the precision supply and reconnect the output of the input amplifier to Terminal 15 (A2).

f. Disconnect the lead to the digital display preamplifier at Terminal 21 (A4). Connect the output of the precision supply between this lead and TP22 (A2J2). Turn the power supply to 4 mV. Adjust A3R2 until the polarity sign changes when the input polarity is reversed. Reduce the power supply voltage and refine the adjustment of A3R2 so that the polarity sign changes with as small a voltage as possible.

g. With the precision power supply still connected, adjust A3R11 until the digital display reading changes from +1 to +2 at between 5.5 mV to 6.5 mV.

h. Disconnect the power supply and replace the lead on Terminal 21 (A4).



DETECTOR

FIGURE 7-1

CAUTION

Take extreme care to insure that no solder creeps back on the spring. Solder on the spring destroys its usefulness and is difficult to remove.

c. Place a pointed tool such as a scribe into the hole in insulator. Melt the solder in the insulator eyelet and remove the insulator. Remove all solder from the insulator eyelet.

d. Remove and discard the old thermistor. Insert the new thermistor. Solder one end of the thermistor to the black lead and clip off any excess lead length.

e. Insert the unsoldered thermistor lead and the red insulated cable conductor into the insulator eyelet. Push the insulator into place. Solder the wires in the eyelet and cut off any excess length. Slip the contact spring over the eyelet and solder the spring to the eyelet. Observe the CAUTION in b. above and use solder sparingly.

f. Let the spring cool, assemble the cap and sleeve to the body assembly and tighten firmly.

7.5 TROUBLE SHOOTING.

In order to localize the source of trouble in an instrument such as this, it is necessary to have a rather detailed working knowledge of the instrument. You are urged to read carefully Section 6 on Circuit Description and make use of the circuit diagrams.

CAUTION

Always turn the power off before removing or inserting an individual PC board. Be sure the PC board is inserted in the connector correctly as indicated in Figure 7-2. If the board is inserted backwards or into the wrong connector, serious damage may occur. If the board is operated on an extender, be particularly careful to see that the orientation of Figure 7-2 is observed. It is also important to handle printed circuit boards carefully during removal and insertion so as not to disturb the settings of the potentiometers which are on them.

7.5.1 LOCALIZATION OF TROUBLE. Use Trouble Shooting Table 7-1. Also make use of the test point information in Section 7.2.

After the trouble has been found and corrected, the calibration should be checked as outlined in Section 7.3.

7.5.2 LOCALIZATION OF TROUBLE TO INDIVIDUAL COMPONENTS. To determine whether a component is defective, it may be necessary to make active or passive circuit checks as well as waveform measurements. Where allowed by circuit voltages, the performance of a transistor that is forward-biased can usually be determined by shorting the base to the emitter or by opening the base circuit. The transistor will be turned off in either case unless it is shorted. Performance may be determined by monitoring circuit parameters. A transistor can be assumed to be open if it does not conduct when its base-to-emitter voltage exceeds turn on.

When checking the FET's used in the Model 1009, shorting the source to drain will result in turn on unless the FET is open. Under normal operating conditions these FET's operate with a negative bias of less than 2 V between the drain and source and a source to drain voltage of at least 5 V unless the unit is shorted. Ohmmeter measurements may be made on the source-gate junction as long as the precautions mentioned below are observed. Back biased, the source-gate junction should be essentially open.

Open or shorted transistors may also be located through resistance measurements across the elements. Exact values cannot be given due to the differences in transistors; however, the ratio of forward and backward emitter-collector resistance is normally between 10:1 and 100:1. Higher power transistors have the lower ratios. If it is determined that a transistor is defective, look for other defective elements in the circuit that may have resulted from, or caused the transistor failure.

When checking resistors and capacitors, one lead should be disconnected to prevent shunt paths and possible damage to diodes and transistors.

CAUTION

1. USE OF OHMMETER. Some ohmmeters may supply sufficient voltage or current to damage transistors. Before using an ohmmeter to check transistors or to make measurements in transistor circuits, be sure to check the voltage and current output of the ohmmeter on the range to be used. The open circuit voltage should not exceed 1.5 V and the short circuit current should not exceed 3 mA or transistors may be damaged. Never use an ohmmeter to check the detector diode. The only safe way to check the detector is to measure the voltage on TP18 (A4J8) with RF input into the detector.

2. MEASURING TRANSISTOR VOLTAGES. Do not measure the base-to-emitter voltage of a transistor directly because auxiliary currents may damage the transistor. Measure the voltages independently with respect to ground.

7.6 PARTS REPLACEMENT.

7.6.1 REPLACEMENT OF PARTS ON PRINTED CIRCUIT BOARDS. Before removing a component from a PC board, carefully note its orientation. Use a low wattage soldering iron (25 W maximum) and apply heat sparingly to the component lead. Be sure that the soldering iron is grounded to prevent leakage current from damaging other components. The simplest way to remove a component with three or more leads is to cut the leads and then unsolder the remaining leads from the PC board. Clear the solder from the PC board holes with a toothpick or an awl for ease of insertion of the new component. To replace the component, form and cut the leads so that they extend approximately 1/16" through the PC board when the component is in position. Whenever possible hold the component lead with a tool that will act as a heat sink and solder the lead from the opposite side. Avoid overheating and use a good quality rosin core solder. Cut off excess lead length and clean off any excess flux.

A break in the etched copper conductor may be repaired by soldering a piece of copper wire across the break. If the bond between the etched copper conductor and the base material fails, secure the conductor in place with a cement having good electrical insulating properties.

7.6.2 REPLACEMENT OF PARTS ON THE FRONT PANEL. Parts mounted on the front panel are accessible by removing the top and bottom covers of the instrument. However, complete access to the rear of the front panel may be obtained by removing the four screws in the corners of the panel flanges and the screw in the center of the top flange. The panel may now be pulled away from the remainder of the unit.

7.6.3 REPLACING THE OFFSET POTENTIOMETERS. To replace the OFFSET potentiometers, proceed as follows: Unsolder the leads from the potentiometers. Remove the OFFSET control knob and the two screws that hold the potentiometer assembly to the panel. Remove the potentiometer assembly from the instrument. Loosen the drive wheel on the potentiometer shaft and the potentiometer retaining nut. The potentiometer may now be removed from the assembly.

7.6.4 REMOVING PLUG-IN PRINTED CIRCUIT BOARDS. The upper portion of the rear panel serves as a hold-down for the two plug-in printed circuit boards. Access to these circuit boards is gained by removing the top cover and the upper portion of the rear panel.

7.6.5 INDICATOR TUBE REPLACEMENT. Access to the indicator tubes is obtained by removing the front panel as described in Section 7.6.2.

7.6.6 UNIT LAMP REPLACEMENT. To replace the unit lamps, proceed as follows: Remove the front panel as described in Section 7.6.2. Remove the two screws that secure the unit mask in front of the lamp holders. Pry off the white lens of the lampholder with a screwdriver or similar instrument. Note the orientation of the lens so that it may be properly replaced. Remove the defective lamp by gripping it with long nose pliers and pulling it straight out of the lampholder.

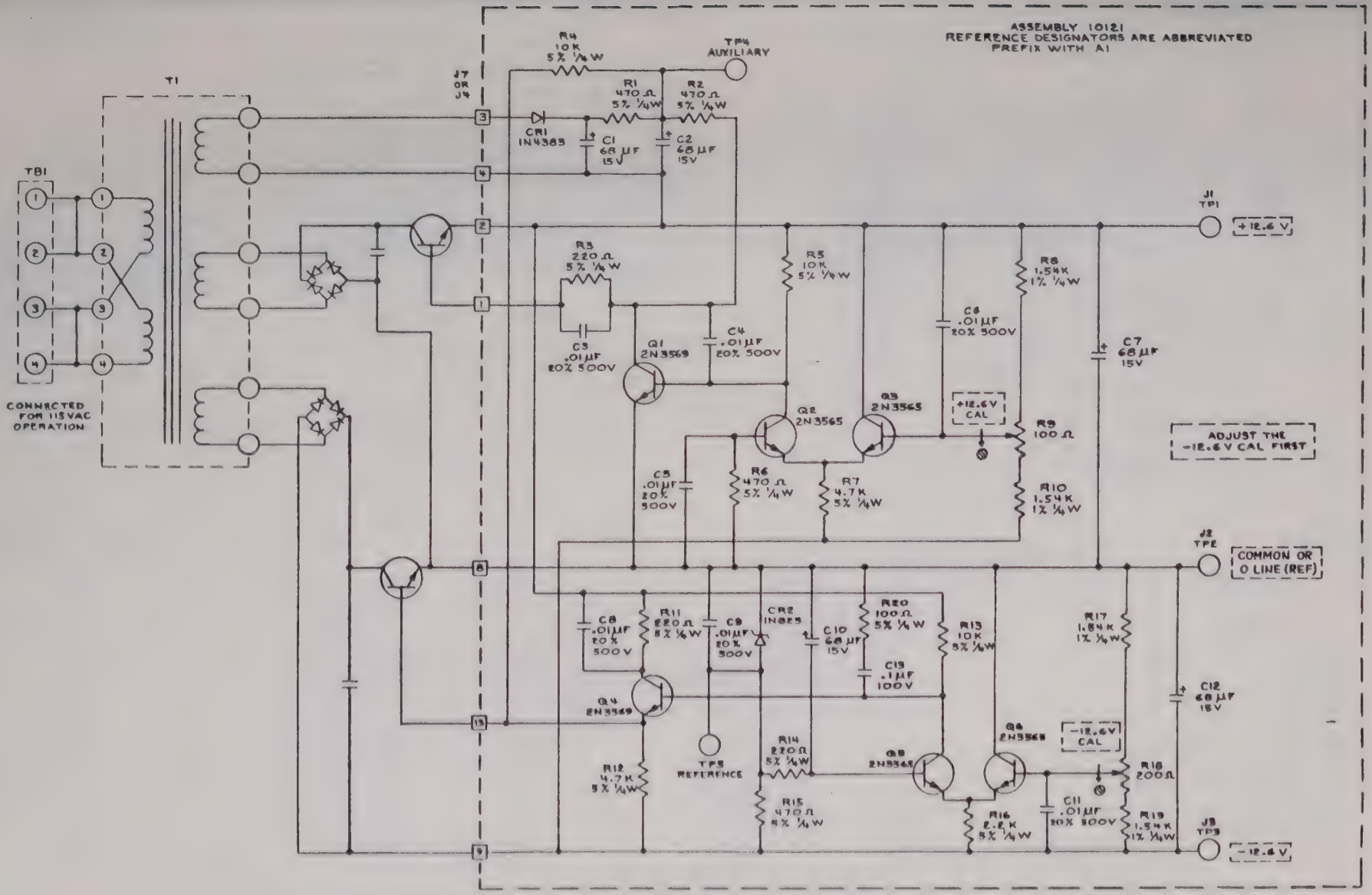
TABLE 7-1 TROUBLE SHOOTING

INDICATION	CHECK
NO DIGITAL DISPLAY	1. Power Cord. 2. Fuse (F1) access to the fuse is through the bottom cover. F1 is 0.5 A 250 V. 3. POWER switch, S1. 4. Transformer, T1. 5. 200 V power supply.
DIGITAL DISPLAY DOES NOT CHANGE	1. DISPLAY TRIGGER switch (rear panel).
INSTRUMENT PROVIDES MEANINGLESS DISPLAY WITH SEVERAL NUMBERS LIT IN EACH DISPLAY TUBE.	1. Check that the 3.6 V supply is operating TP23 (A2J3). 2. Check the logic circuit. Determine that there are 16 pulses at TP25 (A2J5) each measurement cycle. Look for pairs of pulses at Pins 2 and 6 of A2QA14 thru A2QA19 and at Pin 2 of A2QA20. When checking for logic levels within the instrument, it will be found that they vary considerably from IC to IC. The following levels are limits of operation: 1. A low level input may not exceed 400 mV. 2. A high level signal may not fall below 800 mV. 3. Display Trigger Switch (rear panel)
OUT OF CALIBRATION AT ALL SIGNAL LEVELS.	1. Detector, TP18 (A4J8). 2. Power Supplies, A1. 3. Input Amplifier, TP15 (A4J5). 4. Output Amplifier TP6 (A4J6). 5. 4.000 V Power Supply Voltage TP24 (A2J4). 6. A3K1. 7. Perform Calibration.
OPERATES CORRECTLY WITH MOST NUMBERS BUT SOME NUMBERS IN ERROR.	1. Check the components in the approximation circuit corresponding to the numbers in error. Particularly the switching transistor and the summing resistor.
OUT OF CALIBRATION ONLY ABOVE -20 dBm.	1. Computer Amplifier TP11 (A4J1) and TP12 (A4J2).
EXCESSIVE LINE FREQUENCY SIGNAL ON OUTPUT.	1. Grounding of associated test equipment. (Section 5.6)
OUT OF CALIBRATION BELOW -20 dBm ONLY.	1. Zero Control. 2. Chopper Amplifier, TP14 (A4J4).
OUT OF CALIBRATION IN LOG MODE ONLY.	1. X15.4 amplifier. 2. Output amplifier 3. Perform Calibration.
INOPERABLE IN LOG MODES ONLY.	1. Logging Transistor (A4Q10).
WILL NOT RATIO PROPERLY WITH ANOTHER UNIT.	1. Output Amplifier. 2. RATIO/MARKER Input Sensitivity Adjustment (A4R151).

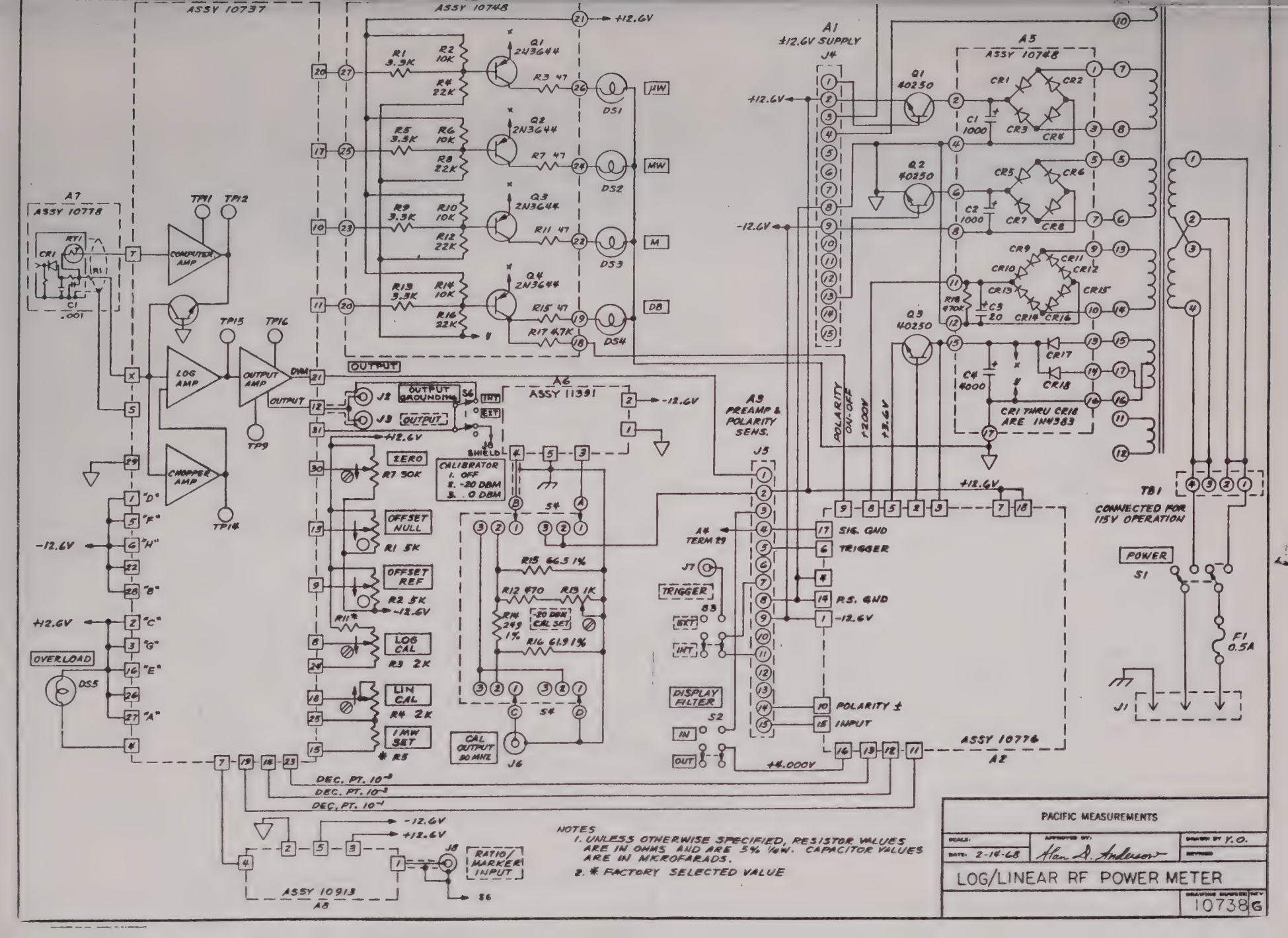
SECTION 8

SCHEMATIC DIAGRAMS

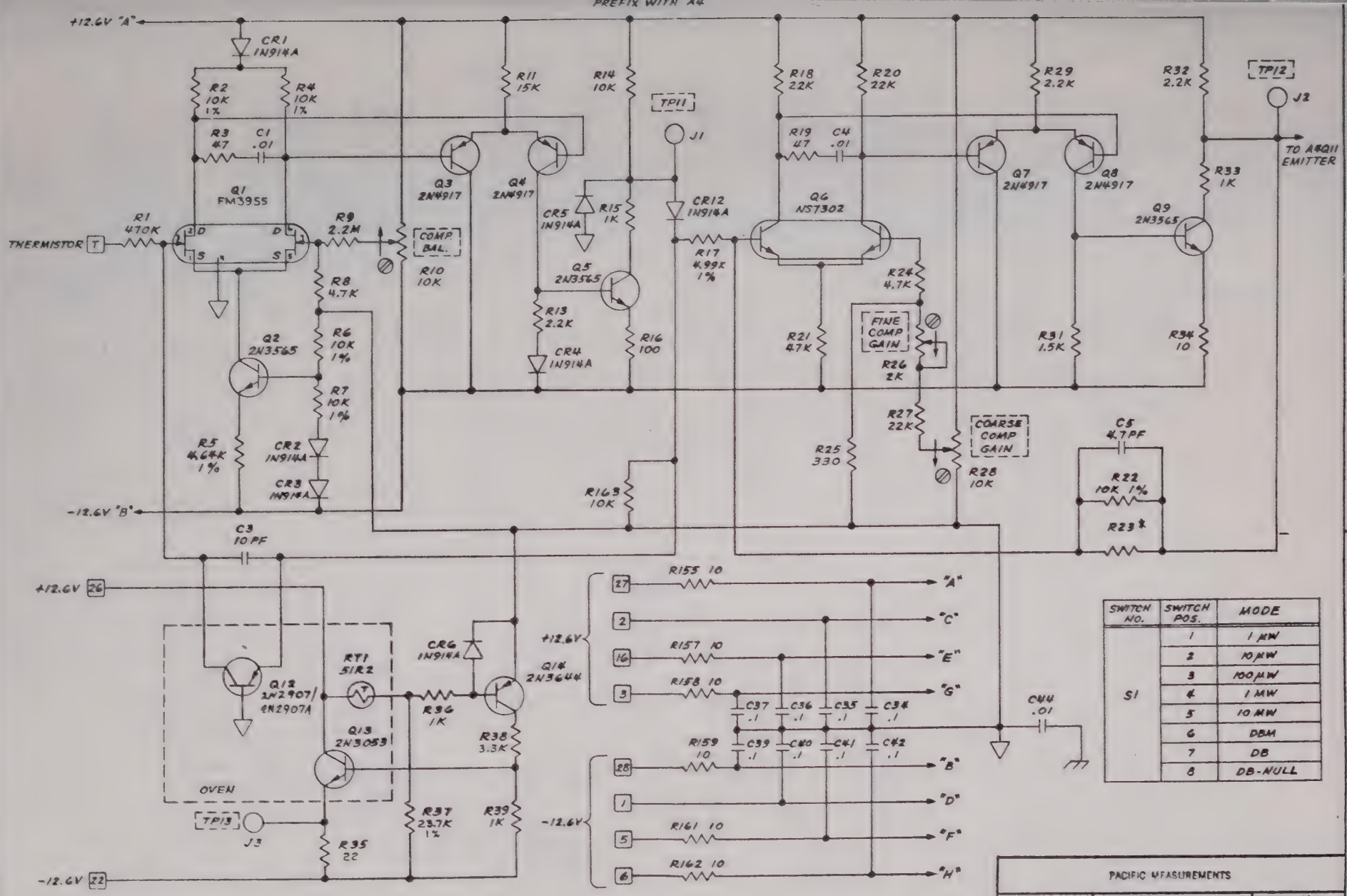
± 12.6 V POWER SUPPLY	10420
LOG/LIN RF POWER METER	10738
CALLIBRATOR OSCILLATOR	11392
INPUT AMPLIFIER (4 SHEETS)	10842
DIGITAL DISPLAY (3 SHEETS)	10843
PREAMPLIFIER AND POLARITY SENSING	11103
RATIO INPUT	10921



PACIFIC MEASUREMENTS		
SCALE:	APPROVED BY:	DRAWN BY AHO
DATE: 1-11-67		REVISED
±12.6 VOLT POWER SUPPLY		DRAWING NUMBER 10420


ASSY 10737
ASSY 10748
A1
±12.6V SUPPLY
A5
ASSY 10748
A7
ASSY 10778
A6
ASSY 11391
A3
PREAMP & POLARITY SENS.
A4
ASSY 10776
A2
A8
ASSY 10913
TB1
CONNECTED FOR 115V OPERATION
POWER
S1
F1
0.5A
J1
CR1 THRU CR18 ARE 1N4383
OUTPUT
ZERO
R7 50K
OFFSET NULL
R1 5K
OFFSET REF
R2 5K
LOG CAL
R3 2K
LIN CAL
R4 2K
1MW SET
* R5
CALIBRATOR
1. OFF
2. -20 DBM
3. 0 DBM
-20 DBM CAL SET
CAL OUTPUT 30 MHZ
J6
TRIGGER
DISPLAY FILTER
OVERLOAD
DS5
SIG. GND
TRIGGER
R.S. GND
-12.6V
POLARITY ±
INPUT
+4.000V
DEC. PT. 10^{-3}
DEC. PT. 10^{-2}
DEC. PT. 10^{-1}
RATIO/MARKER INPUT
NOTES
1. UNLESS OTHERWISE SPECIFIED, RESISTOR VALUES ARE IN OHMS AND ARE 5% 1/4W. CAPACITOR VALUES ARE IN MICROFARADS.
2. * FACTORY SELECTED VALUE
PACIFIC MEASUREMENTS
DATE: 2-16-68
Han D. Anderson
DRAWN BY Y.O.
LOG/LINEAR RF POWER METER
10738 G

PREFIX WITH A4



SWITCH NO.	SWITCH POS.	MODE
S1	1	1 MW
	2	10 MW
	3	100 MW
	4	1 MW
	5	10 MW
	6	DBM
	7	DB
	8	DB-NULL

NOTE:
UNLESS OTHERWISE SPECIFIED, RESISTOR VALUES ARE IN OHMS AND ARE ±5% ¼W. CAPACITOR VALUES ARE IN MICROFARADS.
* FACTORY SELECTED VALUE

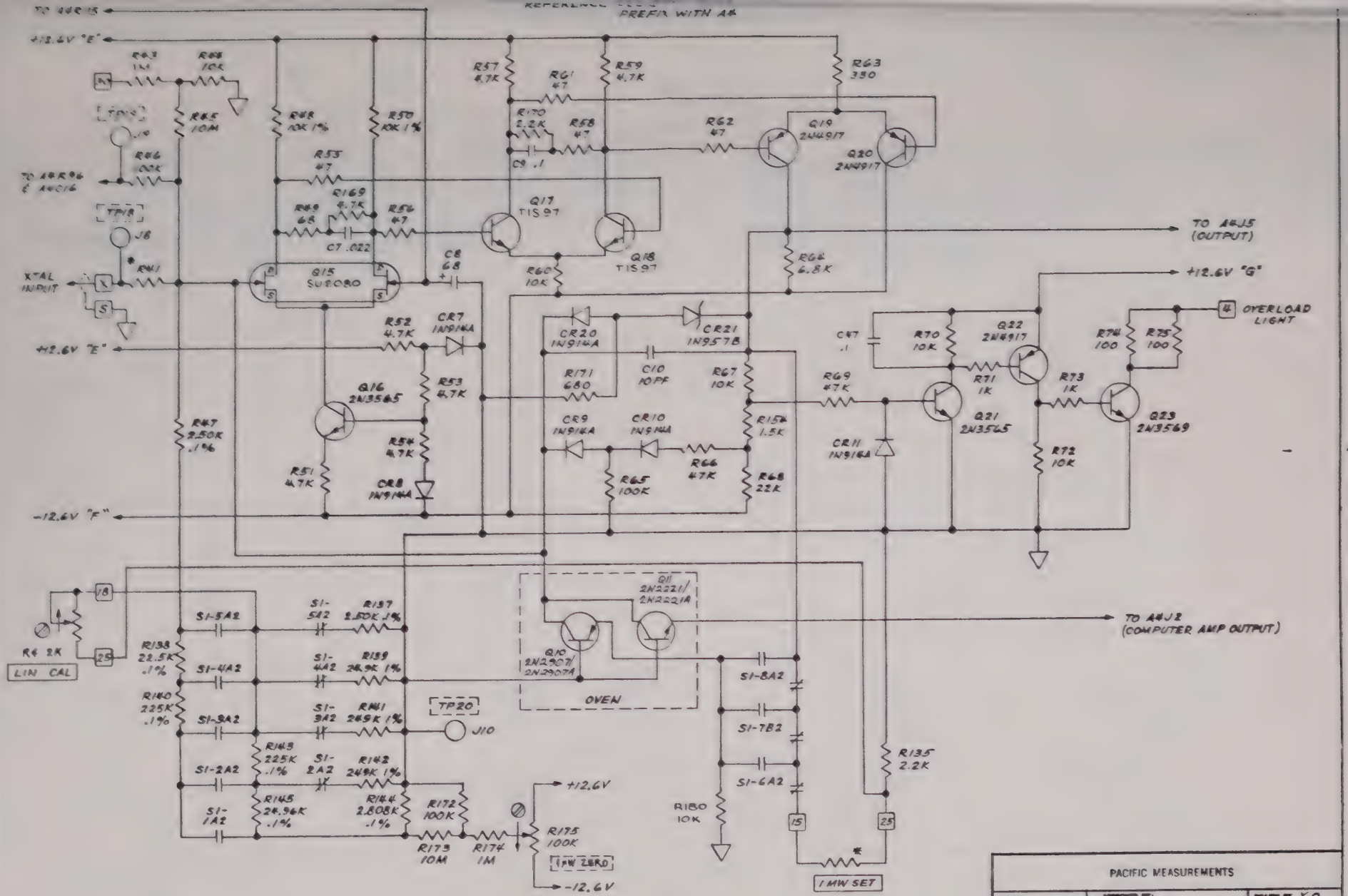
PACIFIC MEASUREMENTS

SCALE: ——	APPROVED BY: Ken N. Jackson	DRAWN BY Y.O.
DATE: 11-16-67		REVISED

INPUT CKT-COMPUTER AMP SECTION

DRAWING NUMBER 10842 REV G

SHT 1 OF



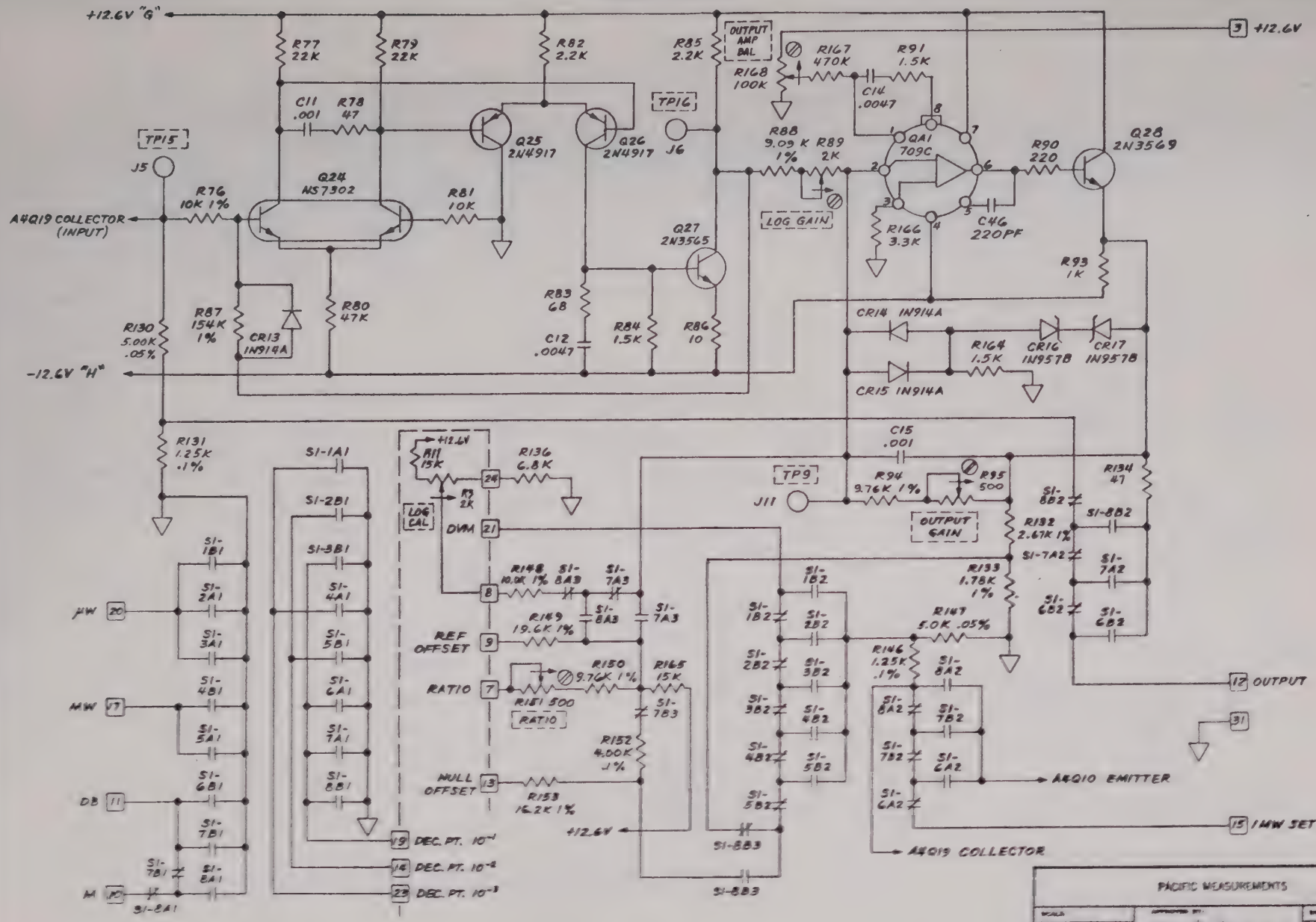
NOTES:

1. UNLESS OTHERWISE SPECIFIED, RESISTOR VALUES ARE IN OHMS AND ARE 5% 1/4W. CAPACITOR VALUES ARE IN MICROFARADS.
2. * FACTORY SELECTED

PACIFIC MEASUREMENTS		
SCALE:	APPROVED BY: Hans A Sulzer	DRAWN BY Y.O.
DATE: 11-7-67		REVISED
INPUT CKT - INPUT AMPLIFIER SECTION		
	DRAWING NUMBER 10842	REV E

SHT 2 OF 4

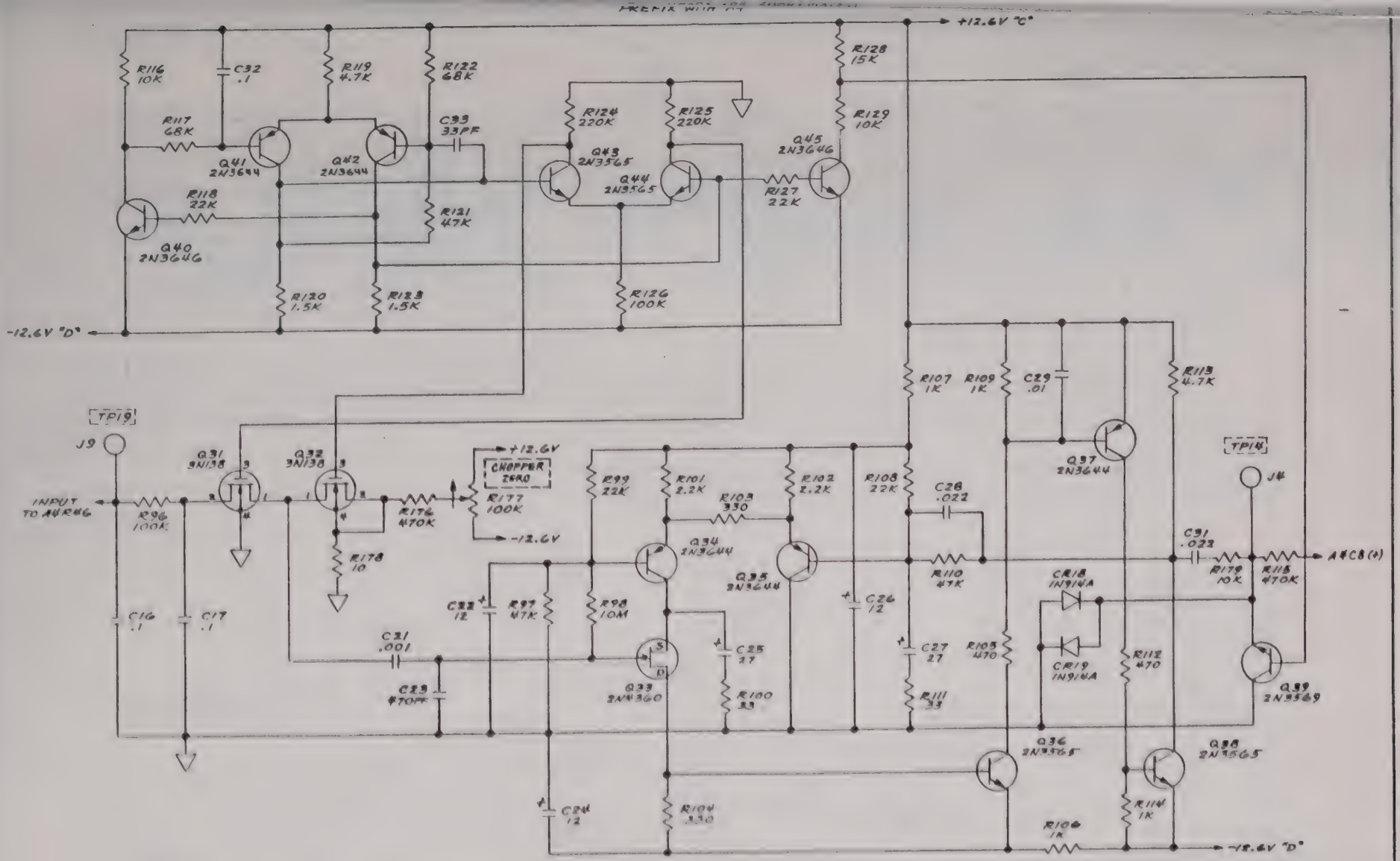
ASSEMBLY 10842
REFERENCE DESIGNATORS ARE ABBREVIATED
PREFIX WITH A4



NOTE:
1. UNLESS OTHERWISE SPECIFIED, RESISTOR VALUES ARE IN OHMS AND ARE 5% 1/4W. CAPACITOR VALUES ARE IN MICROFARADS.
2. * FACTORY SELECTED

PACIFIC MEASUREMENTS		
SCALE	APPROVED BY	DRAWN BY Y.O.
DATE 11-15-67	Ken A Anderson	REVISED
INPUT CKT - OUTPUT AMP SECTION		
	10842	E

SHT 3 OF



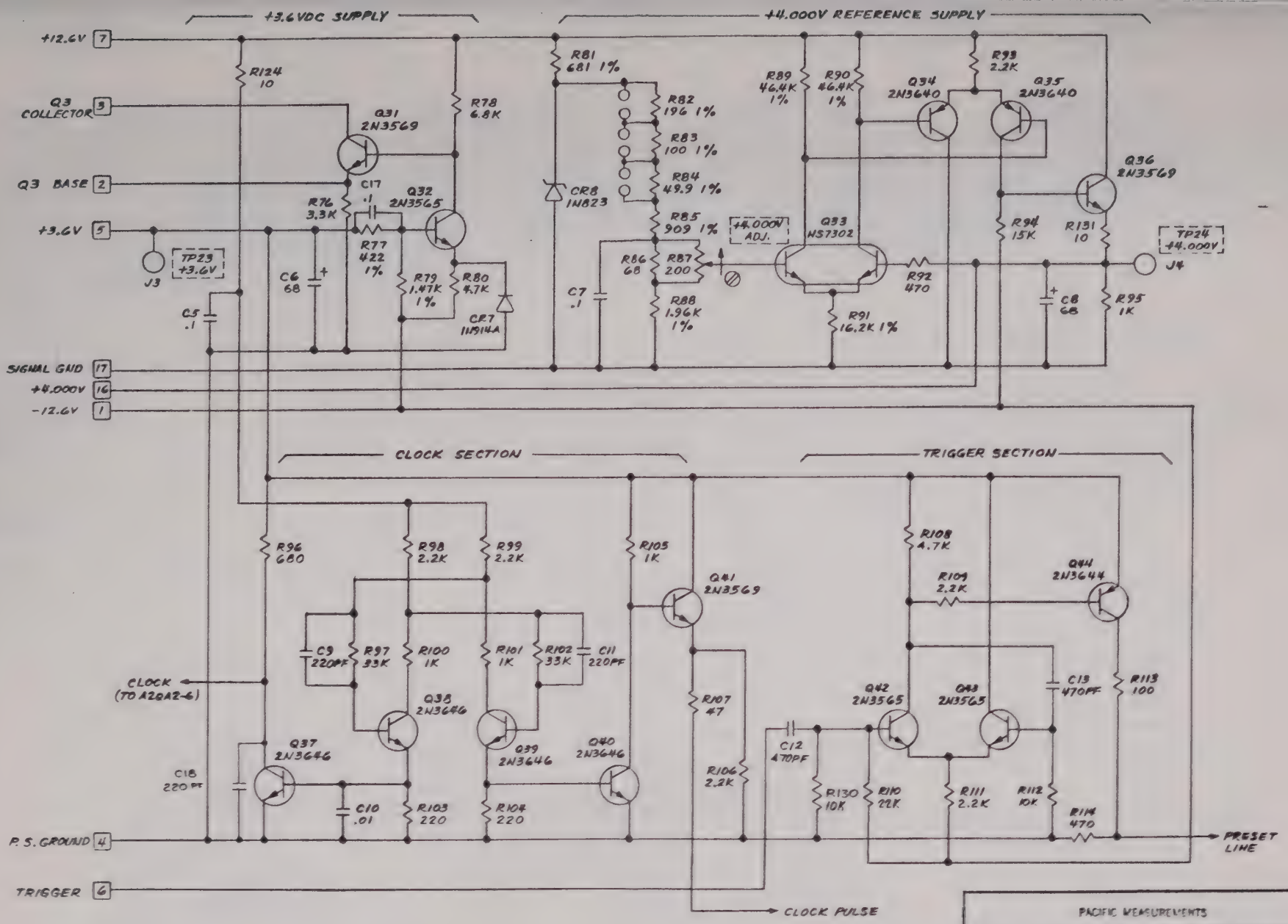
NOTES
UNLESS OTHERWISE SPECIFIED, RESISTOR VALUES ARE IN OHMS AND ARE 5% ¼WATT. CAPACITOR VALUES ARE IN MICROFARADS.

SCALE:	APPROVED BY: Ken Anderson	DRAWN BY Y.C
DATE: 12-6-67		REVISED

INPUT CKT - CHOPPER AMP SECTION

10842 C

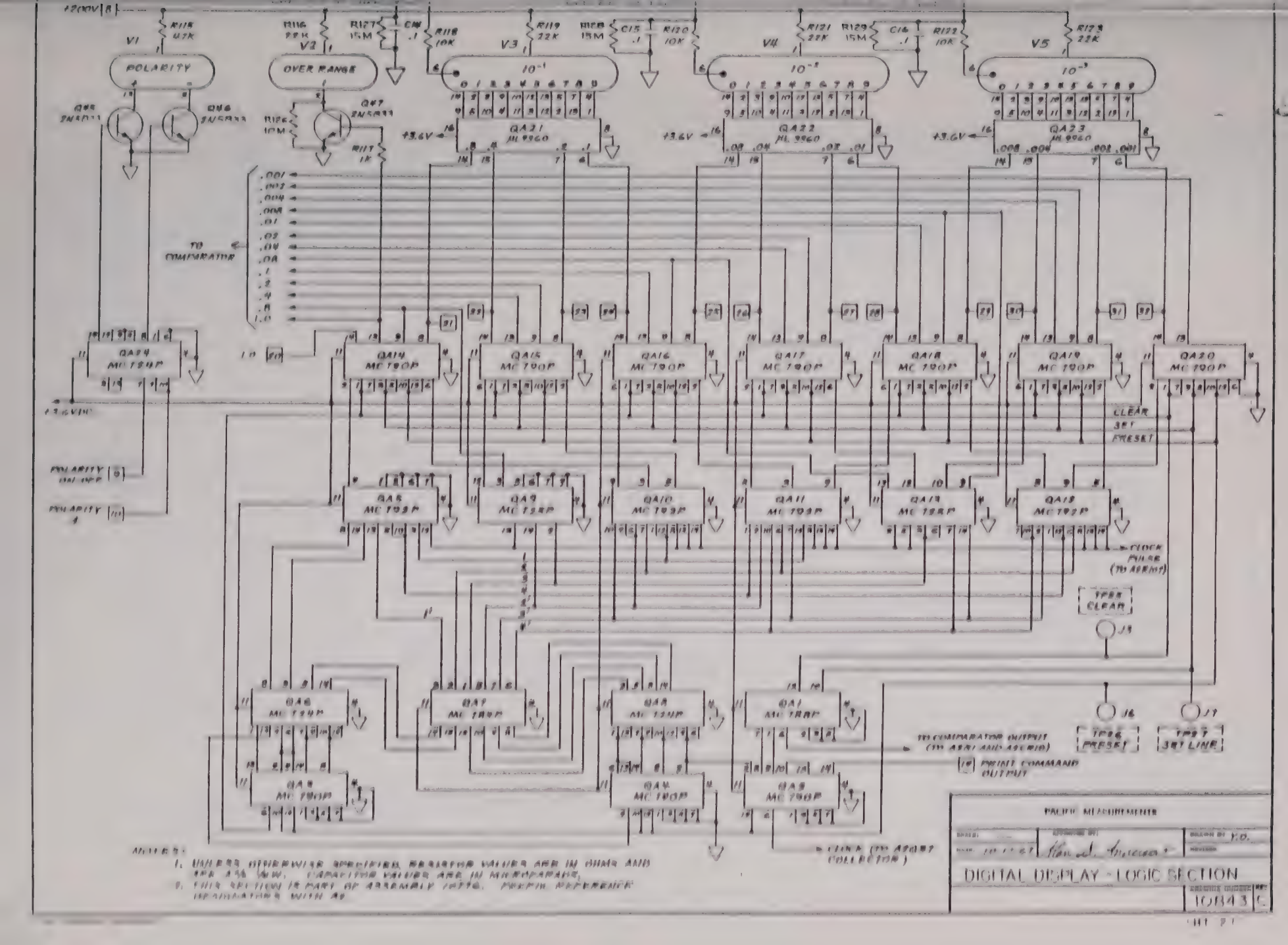
SHT 4 OF 4

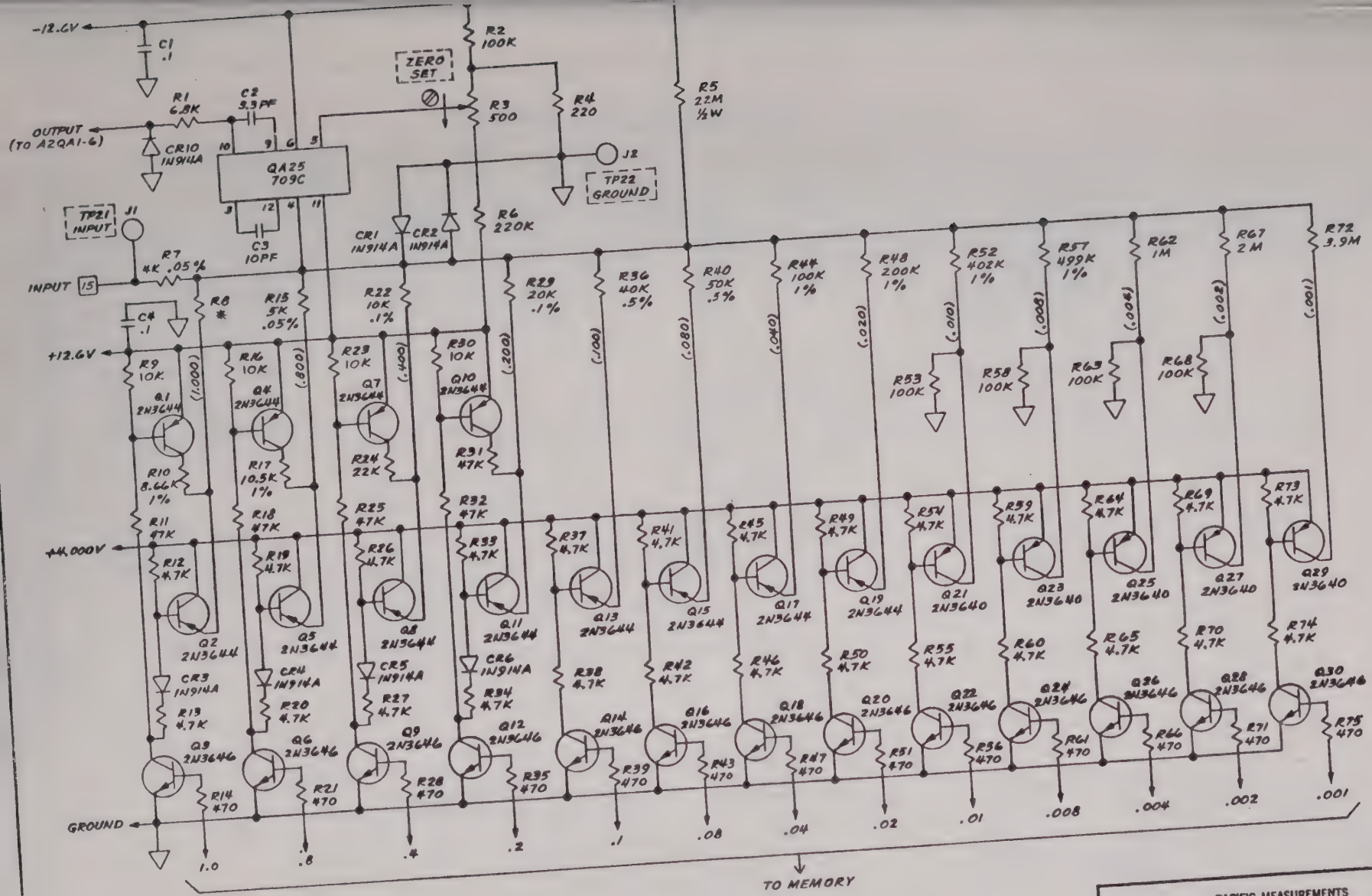


NOTES:

1. UNLESS OTHERWISE SPECIFIED, RESISTOR VALUES ARE IN OHMS AND ARE ±5% ½W. CAPACITOR VALUES ARE IN MICROFARADS.
2. THIS SECTION IS PART OF ASSEMBLY 10776. PREFIX REFERENCE DESIGNATORS WITH A2.

PACIFIC MEASUREMENTS		
SCALE	APPROVED BY: Han S. Anderson	DRAWN BY Y.O.
DATE 11-1-67		REVISED
DIGITAL DISPLAY		
		DRAWING NUMBER 10843F


POLARITY
OVER RANGE
10^{-1}
10^{-2}
10^{-3}
TO COMPARATOR
CLEAR
SET
PRESET
CLOCK PULSE (TO ASSEMBLY)
TP88 CLEAR
TP86 PRESET
TP87 SET LINE
TO COMPARATOR OUTPUT (TO A5A1 AND A5A10)
PRINT COMMAND OUTPUT
PACIFIC MEASUREMENTS
DIGITAL DISPLAY - LOGIC SECTION
10843 C



NOTE
1. UNLESS OTHERWISE SPECIFIED, RESISTOR VALUES ARE IN OHMS AND ARE 5% ¼W. CAPACITOR VALUES ARE IN MICROFARADS.
2 * DENOTES FACTORY SELECTED VALUE.

PACIFIC MEASUREMENTS

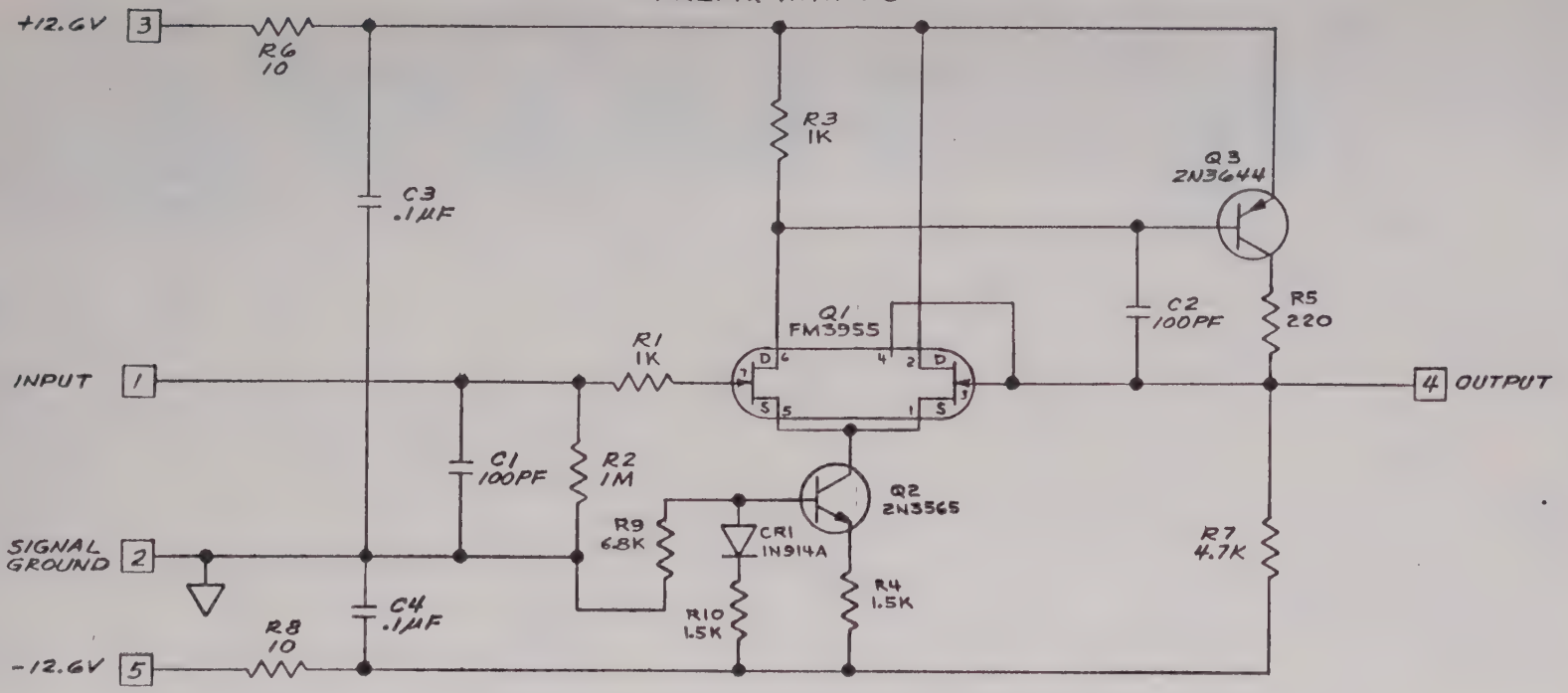
SCALE:	APPROVED BY: Alan A. Anderson	DRAWN BY Y.O.
DATE: 11-17-67		REVISED

DIGITAL DISPLAY - COMPARATOR

DRAWING NUMBER 10843 REV D

SHT 3 OF 3

ASSEMBLY 10913
REFERENCE DESIGNATORS ARE ABBREVIATED
PREFIX WITH A8

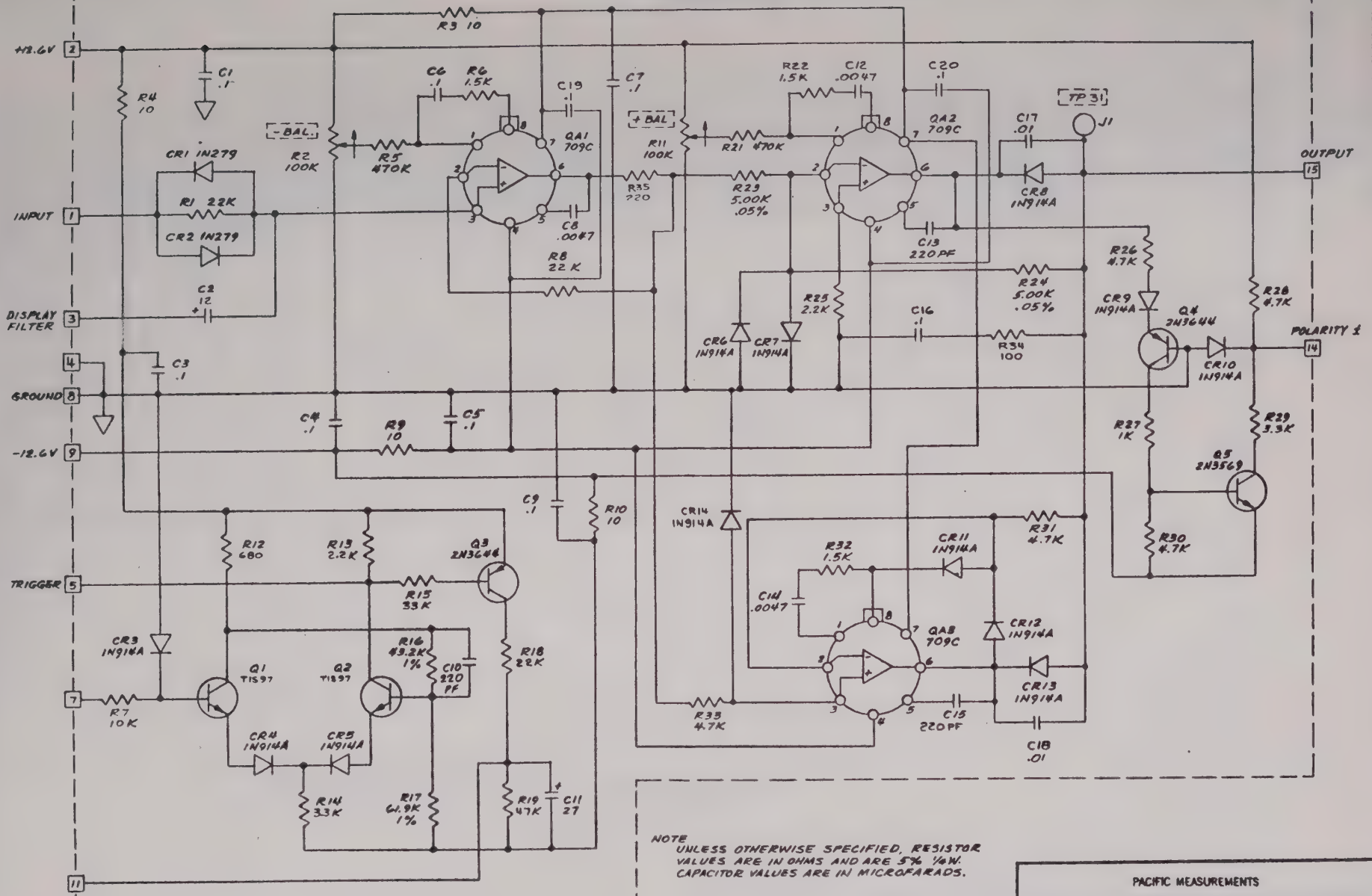


NOTE
UNLESS OTHERWISE SPECIFIED, RESISTOR VALUES ARE IN OHMS AND ARE 5% 1/4 WATT.

PACIFIC MEASUREMENTS		
SCALE:	APPROVED BY:	DRAWN BY Y. O.
DATE: 2-15-68	Alan N. Anderson	REVISED
RATIO INPUT CIRCUIT		
	DRAWING NUMBER 10921	REV C

11X17 PRINTED ON NO. 1000H CLEARPRINT

ASSEMBLY 11102
REFERENCE DESIGNATORS ARE ABBREVIATED
PREFIX WITH A3



NOTE
UNLESS OTHERWISE SPECIFIED, RESISTOR VALUES ARE IN OHMS AND ARE 5% 1/4W.
CAPACITOR VALUES ARE IN MICROFARADS.

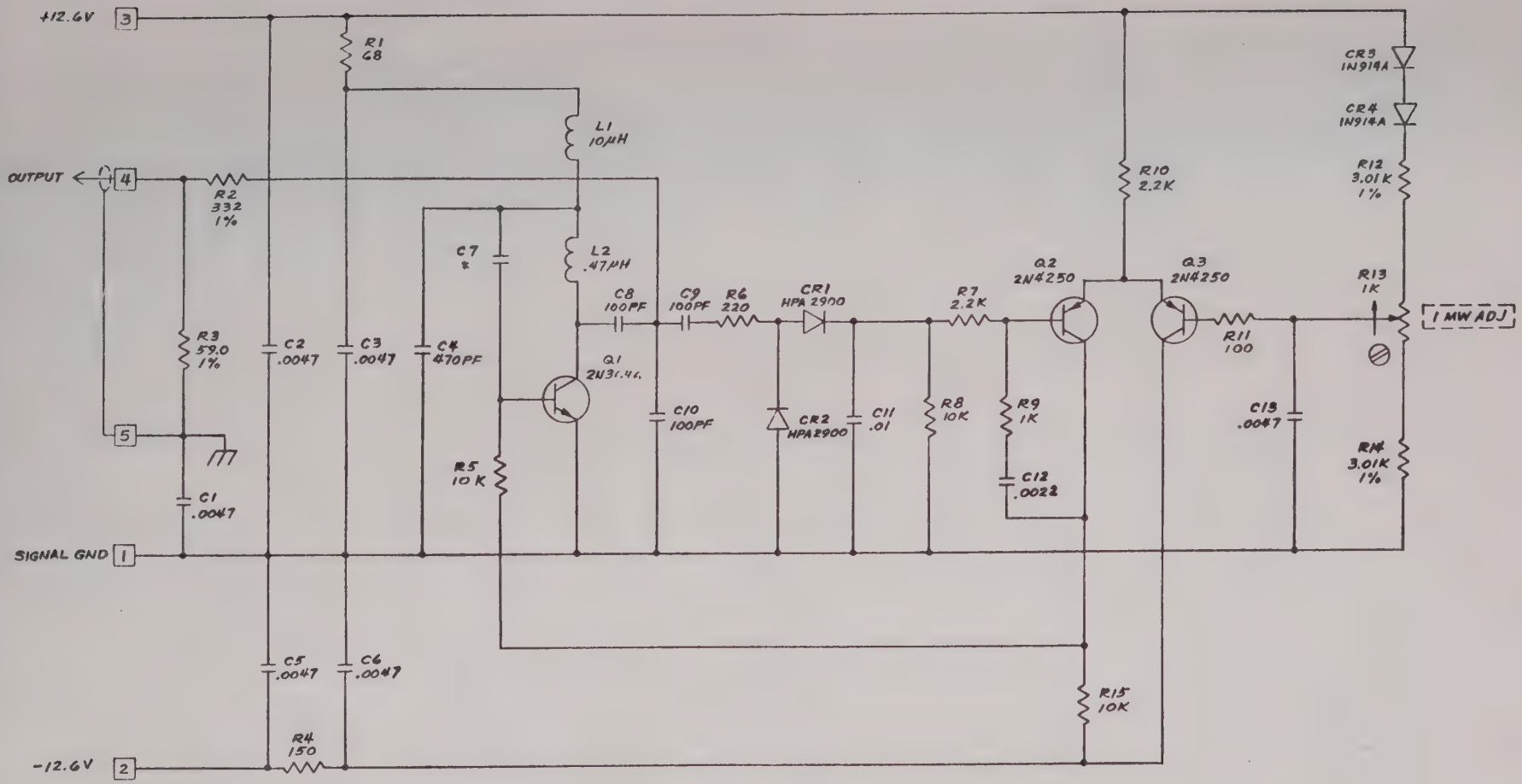
PACIFIC MEASUREMENTS

SCALE: —	APPROVED BY: Ralph Britton	DRAWN BY Y.O.
DATE: 10-15-68		REVISED

PREAMP, POLARITY & TRIGGER CIRCUIT

DRAWING NUMBER 11103 REV F

ASSEMBLY 11391
REFERENCE DESIGNATORS ARE ABBREVIATED
PREFIX WITH AG



NOTE:
1. UNLESS OTHERWISE SPECIFIED RESISTOR VALUES ARE IN OHMS AND ARE ±5% ¼ WATT. CAPACITOR VALUES ARE IN MICROFARADS.
2. * FACTORY SELECTED VALUE

LIST OF MATERIAL

NEXT ASSY

Y.O. 11-17-69

R. BRITTON 12-3-69

PACIFIC MEASUREMENTS INCORPORATED

CALIBRATOR OSCILLATOR

11392 D

SHEET 1 OF 1

SECTION 9

REPLACEABLE PARTS LIST

CIRCUIT REFERENCE	PART NO.	DESCRIPTION
		CHASSIS - 10721
DS1	10712-1	Lamp 6 V 40 mA
DS2	10712-1	Lamp 6 V 40 mA
DS3	10712-1	Lamp 6 V 40 mA
DS4	10712-1	Lamp 6 V 40 mA
DS5	10060-3	Lamp Assembly 14 V Red
F1	10064-2	Fuse 3AG 0.5A 250 V
J1	10052	3 Pin AC Receptable
J2	10048	BNC UG-1094/U
J3	10048	BNC UG-1094/U
J4	10050-1	Connector, PC 15 Contacts
J5	10050-1	Connector, PC 15 Contacts
J6	10821	Type N UG-58A/U
J7	10048	BNC UG-1094/U
J8	10048	BNC UG-1094/U
Q1	10020	Silicon (40250)
Q2	10020	Silicon (40250)
Q3	10020	Silicon (40250)
R1	10217	Variable Wirewound 10 Turn 5 KΩ ± 5%
R2	10217	Variable Wirewound 10 Turn 5KΩ ± 5%
R3	11676-4	Variable Composition 2KΩ ± 30%
R4	11676-4	Variable Composition 2 KΩ ± 30%
R5		Resistor, Factory Selected
R6		Not used
R7	11676-2	Variable Composition 50 KΩ ± 30%
R8		Not Used
R9		Not Used
R10		Not Used
R11	10013-29	Resistor Carbon Film ± 5% 1/4 W Factory Selected Value
R12	10013-21	Carbon Film 470 Ω ± 5% 1/4 W
R13	10095-2	Variable Composition 1 KΩ ± 20% 1/2 W
R14	10015-46	Metal Film 249 Ω ± 1% 1/8 W
R15	10015-103	Metal Film 66.5 Ω ± 1% 1/8 W
R16	10015-82	Metal Film 61.9 Ω ± 1% 1/8 W
S1	10057	Toggle, DPDT
S2	10059	Slide, DPDT
S3	10059	Slide, DPDT
S4	10450	Lever, 5P3T
S5		Not Used
S6	10059	Slide, DPDT
T1	10791	Transformer
XF1	10065	Block, Fuse
		POWER SUPPLY PC BOARD ASSEMBLY - 10121
A1C1	10787-4	Electrolytic 68 µF 15 WVDC
A1C2	10787-4	Electrolytic 68 µF 15 WVDC
A1C3	10000-7	Ceramic 0.01 µF ± 20% 500 VDC
A1C4	10000-7	Ceramic 0.01 µF ± 20% 500 VDC
A1C5	10000-7	Ceramic 0.01 µF ± 20% 500 VDC
A1C6	10000-7	Ceramic 0.01 µF ± 20% 500 VDC
A1C7	10787-4	Electrolytic 68 µF 15 WVDC
A1C8	10000-7	Ceramic 0.01 µF ± 20% 500 VDC
A1C9	10000-7	Ceramic 0.01 µF ± 20% 500 VDC
A1C10	10787-4	Electrolytic 68 µF 15 WVDC
A1C11	10000-7	Ceramic 0.01 µF ± 20% 500 VDC
A1C12	10787-4	Electrolytic 68 µF 15 WVDC
A1C13	10000-10	Ceramic 0.1 µF +80-20% 100 VDC
A1CR1	10044-1	1N4383
A1CR2	10045	1N823
A1J1	10054-2	Test PC Mounting, Red
A1J2	10054-1	Test PC Mounting, Black
A1J3	10054-3	Test PC Mounting, Blue
A1Q1	10017	2N3569
A1Q2	10019	2N3565
A1Q3	10019	2N3565
A1Q4	10017	2N3569
A1Q5	10019	2N3565
A1Q6	10019	2N3565
A1R1	10013-21	Carbon Film 470 Ω ± 5% 1/4 W
A1R2	10013-21	Carbon Film 470 Ω ± 5% 1/4 W
A1R3	10013-17	Carbon Film 220 Ω ± 5% 1/4 W
A1R4	10013-37	Carbon Film 10 KΩ ± 5% 1/4 W
A1R5	10013-37	Carbon Film 10 KΩ ± 5% 1/4 W
A1R6	10013-21	Carbon Film 470 Ω ± 5% 1/4 W
A1R7	10013-33	Carbon Film 4.7 KΩ ± 5% 1/4 W
A1R8	10015-1	Metal Film 1.54 KΩ ± 1% 1/8 W
A1R9	10046-9	Variable Comp. 100 Ω ± 20% Linear 1/4 W
A1R10	10015-1	Metal Film 1.54 KΩ ± 1% 1/8 W
A1R11	10013-17	Carbon Film 220 Ω ± 5% 1/4 W
A1R12	10013-33	Carbon Film 4.7 KΩ ± 5% 1/4 W
A1R13	10013-37	Carbon Film 10 KΩ ± 5% 1/4 W
A1R14	10013-17	Carbon Film 220 Ω ± 5% 1/4 W
A1R15	10013-21	Carbon Film 470 Ω ± 5% 1/4 W
A1R16	10013-29	Carbon Film 2.2 KΩ ± 5% 1/4 W
A1R17	10015-1	Metal Film 1.54 KΩ ± 1% 1/8 W
A1R18	10046-6	Variable Comp. 200 Ω ± 20% Linear 1/4 W
A1R19	10015-1	Metal Film 1.54 KΩ ± 1% 1/8 W
A1R20	10013-13	Carbon Film 100 Ω ± 5% 1/4 W
		DIGITAL DISPLAY PC BOARD ASSEMBLY - 10776
A2C1	10000-10	Ceramic 0.1 µF -20 + 80% 100 V
A2C2	10001-12	Ceramic NPO 3.3 pF 5% 1000 V
A2C3	10001-3	Ceramic NPO 10 pF 5% 1000 V
A2C4	10000-10	Ceramic 0.1 µF -20 + 80% 100 V
A2C5	10000-10	Ceramic 0.1 µF -20 + 80% 100 V
A2C6	10787-4	Electrolytic 68 µF 15 V
A2C7	10000-10	Ceramic 0.1 µF -20 + 80% 100 V
A2C8	10787-4	Electrolytic 68 µF 15 V
A2C9	10000-2	Ceramic 220 pF ± 20% 1000 V
A2C10	10000-7	Ceramic 0.01 µF ± 20% 500 V
A2C11	10000-2	Ceramic 220 pF ± 20% 1000 V
A2C12	10585-3	Ceramic 470 pF ± 5% 1000 V

CIRCUIT REFERENCE	PART NO.	DESCRIPTION
A2C13	10000-3	Ceramic 470 pF ± 20% 1000 V
A2C14	10000-10	Ceramic 0.1 µF -20% + 80% 100 V
A2C15	10000-10	Ceramic 0.1 µF -20% + 80% 100 V
A2C16	10000-10	Ceramic 0.1 µF -20% + 80% 100 V
A2C17	10000-10	Ceramic 0.1 µF -20% + 80% 100 V
A2C18	10000-2	Ceramic 220 pf ±20% 1000 V
A2CR1	10043	1N914A
A2CR2	10043	1N914A
A2CR3	10043	1N914A
A2CR4	10043	1N914A
A2CR5	10043	1N914A
A2CR6	10043	1N914A
A2CR7	10043	1N914A
A2CR8	10045	1N823
A2CR9		Not Used.
A2CR10	10043	1N914A
A2J1	10140-2	Test Jack, Yellow
A2J2	10140-2	Test Jack, Yellow
A2J3	10140-1	Test Jack, Red
A2J4	10140-1	Test Jack, Red
A2J5	10140-2	Test Jack, Yellow
A2J6	10140-2	Test Jack, Yellow
A2J7	10140-2	Test Jack, Yellow
A2Q1	10023	2N3644
A2Q2	10023	2N3644
A2Q3	10018	2N3646
A2Q4	10023	2N3644
A2Q5	10023	2N3644
A2Q6	10018	2N3646
A2Q7	10023	2N3644
A2Q8	10023	2N3644
A2Q9	10018	2N3646
A2Q10	10023	2N3644
A2Q11	10023	2N3644
A2Q12	10018	2N3646
A2Q13	10023	2N3644
A2Q14	10018	2N3646
A2Q15	10023	2N3644
A2Q16	10018	2N3646
A2Q17	10023	2N3644
A2Q18	10018	2N3646
A2Q19	10023	2N3644
A2Q20	10018	2N3646
A2Q21	10022	2N3640
A2Q22	10018	2N3646
A2Q23	10022	2N3640
A2Q24	10018	2N3646
A2Q25	10022	2N3640
A2Q26	10018	2N3646
A2Q27	10022	2N3640
A2Q28	10018	2N3646
A2Q29	10022	2N3640
A2Q30	10018	2N3646
A2Q31	10017	2N3569
A2Q32	10019	2N3565
A2Q33	10312	NS7302
A2Q34	10022	2N3640
A2Q35	10022	2N3640
A2Q36	10017	2N3569
A2Q37	10018	2N3646
A2Q38	10018	2N3646
A2Q39	10018	2N3646
A2Q40	10018	2N3646
A2Q41	10017	2N3569
A2Q42	10019	2N3565
A2Q43	10019	2N3565
A2Q44	10023	2N3644
A2Q45	11692	2N5833
A2Q46	11692	2N5833
A2Q47	11692	2N5833
A2QA1	10722-3	Motorola MC 788p (Dual Buffer)
A2QA2	10722-5	Motorola MC 790p (Dual J-K Flip-Flop)
A2QA3	10722-5	Motorola MC 790p (Dual J-K Flip-Flop)
A2QA4	10722-5	Motorola MC 790p (Dual J-K Flip-Flop)
A2QA5	10722-6	Motorola MC 792p (Triple 3 Input Gate)
A2QA6	10722-1	Motorola MC 724p (Quad 2 Input Gate)
A2QA7	10722-4	Motorola MC 789p (Hex Inverter)
A2QA8	10722-1	Motorola MC 724p (Quad 2 Input Gate)
A2QA9	10722-2	Motorola MC 725p (Dual 4 Input Gate)
A2QA10	10722-6	Motorola MC 792p (Triple 3 Input Gate)
A2QA11	10722-6	Motorola MC 792p (Triple 3 Input Gate)
A2QA12	10722-6	Motorola MC 792p (Triple 3 Input Gate)
A2QA13	10722-2	Motorola MC 725p (Dual 4 Input Gate)
A2QA14	10722-5	Motorola MC 790p (Dual J-K Flip-Flop)
A2QA15	10722-5	Motorola MC 790p (Dual J-K Flip-Flop)
A2QA16	10722-5	Motorola MC 790p (Dual J-K Flip-Flop)
A2QA17	10722-5	Motorola MC 790p (Dual J-K Flip-Flop)
A2QA18	10722-5	Motorola MC 790p (Dual J-K Flip-Flop)
A2QA19	10722-5	Motorola MC 790p (Dual J-K Flip-Flop)
A2QA20	10722-5	Motorola MC 790p (Dual J-K Flip-Flop)
A2QA21	10728	Fairchild µL 9960 (Decoder Driver)
A2QA22	10728	Fairchild µL 9960 (Decoder Driver)
A2QA23	10728	Fairchild µL 9960 (Decoder Driver)
A2QA24	10722-1	Motorola MC 724p (Quad 2 Input Gate)
A2QA25	10743	Motorola MC 1709cp (Op. Amplifier)

CIRCUIT REFERENCE	PART NO.	DESCRIPTION
A2R1	10013-35	Carbon Film 6.8 KΩ ± 5% 1/4 W
A2R2	10013-49	Carbon Film 100 KΩ ± 5% 1/4 W
A2R3	10046-1	Variable Composition 500 Ω 20% 1/4 W
A2R4	10013-17	Carbon Film 220 Ω ± 5% 1/4 W
A2R5	10142-4	Carbon Composition 22 MΩ ± 5% 1/4 W
A2R6	10013-53	Carbon Film 220 KΩ ± 5% 1/4 W
A2R7	10725-1	Precision Wirewound 4 KΩ ± .05% 1/8 W
A2R8	--	Factory Selected Value
A2R9	10013-37	Carbon Film 10 KΩ ± 5% 1/4 W
A2R10	10015-57	Metal Film 8.66 KΩ ± 1% 1/8 W
A2R11	10013-45	Carbon Film 47 KΩ ± 5% 1/4 W
A2R12	10013-33	Carbon Film 4.7 KΩ ± 5% 1/4 W
A2R13	10013-33	Carbon Film 4.7 KΩ ± 5% 1/4 W
A2R14	10013-21	Carbon Film 470 Ω ± 5% 1/4 W
A2R15	10725-2	Precision Wirewound 5 KΩ .05% 1/8 W
A2R16	10013-37	Carbon Film 10 KΩ ± 5% 1/4 W
A2R17	10015-59	Metal Film 10.5 KΩ ± 1% 1/8 W
A2R18	10013-45	Carbon Film 47 KΩ ± 5% 1/4 W
A2R19	10013-33	Carbon Film 4.7 KΩ ± 5% 1/4 W
A2R20	10013-33	Carbon Film 4.7 KΩ ± 5% 1/4 W
A2R21	10013-21	Carbon Film 470 Ω ± 5% 1/4 W
A2R22	12449-21	Metal Film 10 KΩ 0.1%
A2R23	10013-37	Carbon Film 10 KΩ ± 5% 1/4 W
A2R24	10013-41	Carbon Film 22 KΩ ± 5% 1/4 W
A2R25	10013-45	Carbon Film 47 KΩ ± 5% 1/4 W
A2R26	10013-33	Carbon Film 4.7 KΩ ± 5% 1/4 W
A2R27	10013-33	Carbon Film 4.7 KΩ ± 5% 1/4 W
A2R28	10013-21	Carbon Film 470 Ω ± 5% 1/4 W
A2R29	12449-37	Metal Film 20 KΩ ± 0.1% 1/8 W
A2R30	10013-37	Carbon Film 10 KΩ ± 5% 1/4 W
A2R31	10013-45	Carbon Film 47 KΩ ± 5% 1/4 W
A2R32	10013-45	Carbon Film 47 KΩ ± 5% 1/4 W
A2R33	10013-33	Carbon Film 4.7 KΩ ± 5% 1/4 W
A2R34	10013-33	Carbon Film 4.7 KΩ ± 5% 1/4 W
A2R35	10013-21	Carbon Film 470 Ω ± 5% 1/4 W
A2R36	10727-1	Precision Wirewound 40 KΩ 0.5% 1/8 W
A2R37	10013-33	Carbon Film 4.7 KΩ ± 5% 1/4 W
A2R38	10013-33	Carbon Film 4.7 KΩ ± 5% 1/4 W
A2R39	10013-21	Carbon Film 470 Ω ± 5% 1/4 W
A2R40	10727-2	Precision Wirewound 50 KΩ 0.5% 1/8 W
A2R41	10013-33	Carbon Film 4.7 KΩ ± 5% 1/4 W
A2R42	10013-33	Carbon Film 4.7 KΩ ± 5% 1/4 W
A2R43	10013-21	Carbon Film 470 Ω ± 5% 1/4 W
A2R44	10015-13	Metal Film 100 kΩ ± 1% 1/8 W
A2R45	10013-33	Carbon Film 4.7 KΩ ± 5% 1/4 W
A2R46	10013-33	Carbon Film 4.7 KΩ ± 5% 1/4 W
A2R47	10013-21	Carbon Film 470 Ω ± 5% 1/4 W
A2R48	10015-62	Metal Film 200 KΩ ± 1% 1/8 W
A2R49	10013-33	Carbon Film 4.7 KΩ ± 5% 1/4 W
A2R50	10013-33	Carbon Film 4.7 KΩ ± 5% 1/4 W
A2R51	10013-21	Carbon Film 470 Ω ± 5% 1/4 W
A2R52	10015-63	Metal Film 402 KΩ ± 1% 1/8 W
A2R53	10013-49	Carbon Film 100 KΩ ± 5% 1/4 W
A2R54	10013-33	Carbon Film 4.7 KΩ ± 5% 1/4 W
A2R55	10013-33	Carbon Film 4.7 KΩ ± 5% 1/4 W
A2R56	10013-21	Carbon Film 470 Ω ± 5% 1/4 W
A2R57	10015-45	Metal Film 499 KΩ ± 1% 1/8 W
A2R58	10013-49	Carbon Film 100 KΩ ± 5% 1/4 W
A2R59	10013-33	Carbon Film 4.7 KΩ ± 5% 1/4 W
A2R60	10013-33	Carbon Film 4.7 KΩ ± 5% 1/4 W
A2R61	10013-21	Carbon Film 470 Ω ± 5% 1/4 W
A2R62	10013-61	Carbon Film 1 MΩ ± 5% 1/4 W
A2R63	10013-49	Carbon Film 100 KΩ ± 5% 1/4 W
A2R64	10013-33	Carbon Film 4.7 KΩ ± 5% 1/4 W
A2R65	10013-33	Carbon Film 4.7 KΩ ± 5% 1/4 W
A2R66	10013-21	Carbon Film 470 Ω ± 5% 1/4 W
A2R67	10013-74	Carbon Film 2 MΩ ± 5% 1/4 W
A2R68	10013-49	Carbon Film 100 KΩ ± 5% 1/4 W
A2R69	10013-33	Carbon Film 4.7 KΩ ± 5% 1/4 W
A2R70	10013-33	Carbon Film 4.7 KΩ ± 5% 1/4 W
A2R71	10013-21	Carbon Film 470 Ω ± 5% 1/4 W
A2R72	10013-68	Carbon Film 3.9 MΩ ± 5% 1/4 W
A2R73	10013-33	Carbon Film 4.7 KΩ ± 5% 1/4 W
A2R74	10013-33	Carbon Film 4.7 KΩ ± 5% 1/4 W
A2R75	10013-21	Carbon Film 470 Ω ± 5% 1/4 W
A2R76	10013-31	Carbon Film 3.3 KΩ ± 5% 1/4 W
A2R77	10015-29	Metal Film 422 Ω ± 1% 1/8 W
A2R78	10013-35	Carbon Film 6.8 KΩ ± 5% 1/4 W
A2R79	10015-50	Metal Film 1.47 KΩ ± 1% 1/8 W
A2R80	10013-33	Carbon Film 4.7 KΩ ± 5% 1/4 W
A2R81	10015-70	Metal Film 681 Ω ± 1% 1/8 W
A2R82	10015-69	Metal Film 196 Ω ± 1% 1/8 W
A2R83	10015-68	Metal Film 100 Ω ± 1% 1/8 W
A2R84	10015-3	Metal Film 49.9 Ω ± 1% 1/8 W
A2R85	10015-71	Metal Film 909 Ω ± 1% 1/8 W
A2R86	10013-11	Carbon Film 68 Ω ± 5% 1/4 W
A2R87	10046-6	Variable Composition 200 Ω ± 20% 1/4 W
A2R88	10015-72	Metal Film 1.96 KΩ ± 1% 1/8 W
A2R89	10015-24	Metal Film 46.4 KΩ ± 1% 1/8 W
A2R90	10015-24	Metal Film 46.4 KΩ ± 1% 1/8 W
A2R91	10015-11	Metal Film 16.2 KΩ ± 1% 1/8 W
A2R92	10013-21	Carbon Film 470 Ω ± 5% 1/4 W
A2R93	10013-29	Carbon Film 2.2 KΩ ± 5% 1/4 W
A2R94	10013-39	Carbon Film 15 KΩ ± 5% 1/4 W
A2R95	10013-25	Carbon Film 1 KΩ ± 5% 1/4 W
A2R96	10013-23	Carbon Film 680 Ω ± 5% 1/4 W
A2R97	10013-43	Carbon Film 33 KΩ ± 5% 1/4 W
A2R98	10013-29	Carbon Film 2.2 KΩ ± 5% 1/4 W
A2R99	10013-29	Carbon Film 2.2 KΩ ± 5% 1/4 W
A2R100	10013-25	Carbon Film 1 KΩ ± 5% 1/4 W
A2R101	10013-25	Carbon Film 1 KΩ ± 5% 1/4 W
A2R102	10013-43	Carbon Film 33 KΩ ± 5% 1/4 W
A2R103	10013-17	Carbon Film 220 Ω ± 5% 1/4 W
A2R104	10013-17	Carbon Film 220 Ω ± 5% 1/4 W
A2R105	10013-25	Carbon Film 1 KΩ ± 5% 1/4 W
A2R106	10013-29	Carbon Film 2.2 KΩ ± 5% 1/4 W
A2R107	10013-9	Carbon Film 47 Ω ± 5% 1/4 W
A2R108	10013-33	Carbon Film 4.7 KΩ ± 5% 1/4 W
A2R109	10013-29	Carbon Film 2.2 KΩ ± 5% 1/4 W
A2R110	10013-41	Carbon Film 22 KΩ ± 5% 1/4 W
A2R111	10013-29	Carbon Film 2.2 KΩ ± 5% 1/4 W
A2R112	10013-37	Carbon Film 10 KΩ ± 5% 1/4 W
A2R113	10013-13	Carbon Film 100 Ω ± 5% 1/4 W
A2R114	10013-21	Carbon Film 470 Ω ± 5% 1/4 W
A2R115	10013-45	Carbon Film 47 KΩ ± 5% 1/4 W
A2R116	10013-41	Carbon Film 22 KΩ ± 5% 1/4 W
A2R117	10013-25	Carbon Film 1 KΩ ± 5% 1/4 W
A2R118	10013-37	Carbon Film 10 KΩ ± 5% 1/4 W
A2R119	10013-41	Carbon Film 22 KΩ ± 5% 1/4 W
A2R120	10013-37	Carbon Film 10 KΩ ± 5% 1/4 W
A2R121	10013-41	Carbon Film 22 KΩ ± 5% 1/4 W
A2R122	10013-37	Carbon Film 10 KΩ ± 5% 1/4 W
A2R123	10013-41	Carbon Film 22 KΩ ± 5% 1/4 W
A2R124	10013-1	Carbon Film 10 Ω ± 5% 1/4 W
A2R125		Not Used
A2R126	10013-73	Carbon Film 10 MΩ ± 5% 1/4 W
A2R127	10142-2	Carbon Comp 15 MΩ ± 5% 1/4 W
A2R128	10142-2	Carbon Comp 15 MΩ ± 5% 1/4 W
A2R129	10142-2	Carbon Comp 15 MΩ ± 5% 1/4 W
A2R130	10013-37	Carbon Film 10 K ± 5% 1/4 W
A2R131	10013-1	Carbon Film 10Ω ±5% 1/4 W
A2V1	10724	Polarity Readout
A2V2	10723	Numeral Readout
A2V3	10723	Numeral Readout
A2V4	10723	Numeral Readout
A2V5	10723	Numeral Readout

CIRCUIT REFERENCE	PART NO.	DESCRIPTION
A4C44	10000-7	Ceramic .01 µF ± 20% 500 VDC
A4C45		Not Used
A4C46	10000-2	Ceramic 220 pF ± 20% 1000 VDC
A4C47	10000-10	Ceramic .1 µF +80-20% 100 VDC
A4CR1	10043	1N914A
A4CR2	10043	1N914A
A4CR3	10043	1N914A
A4CR4	10043	1N914A
A4CR5	10043	1N914A
A4CR6	10043	1N914A
A4CR7	10043	1N914A
A4CR8	10043	1N914A
A4CR9	10043	1N914A
A4CR10	10043	1N914A
A4CR11	10043	1N914A
A4CR12	10043	1N914A
A4CR13	10043	1N914A
A4CR14	10043	1N914A
A4CR15	10043	1N914A
A4CR16	10885	1N957B
A4CR17	10885	1N957B
A4CR18	10043	1N914A
A4CR19	10043	1N914A
A4CR20	10043	1N914A
A4CR21	11450	1N957B Selected
A4J1	10140-2	Test Jack, Yellow
A4J2	10140-2	Test Jack, Yellow
A4J3	10140-2	Test Jack, Yellow
A4J4	10140-2	Test Jack, Yellow
A4J5	10140-2	Test Jack, Yellow
A4J6	10140-2	Test Jack, Yellow
A4J7		Not Used
A4J8	10140-2	Test Jack, Yellow
A4J9	10140-2	Test Jack, Yellow
A4J10	10140-2	Test Jack, Yellow
A4J11	10140-2	Test Jack, Yellow
A4Q1	11432	FM3955 (National)
A4Q2	10019	2N3565
A4Q3	10398	2N4917
A4Q4	10398	2N4917
A4Q5	10019	2N3565
A4Q6	10312	NS7302
A4Q7	10398	2N4917
A4Q8	10398	2N4917
A4Q9	10019	2N3565
A4Q10	13533	2N2907/2N2907A
A4Q11	13543	2N2221/2N2221A
A4Q12	13533	2N2907/2N2907A
A4Q13	10206	2N3053
A4Q14	10023	2N3644
A4Q15	10207	SU2080 (AMELCO)
A4Q16	10019	2N3565
A4Q17	11507	TIS 97 (TI)
A4Q18	11507	TIS 97 (TI)
A4Q19	10398	2N4917
A4Q20	10398	2N4917
A4Q21	10019	2N3565
A4Q22	10398	2N4917
A4Q23	10017	2N3569
A4Q24	10312	NS7302
A4Q25	10398	2N4917
A4Q26	10398	2N4917
A4Q27	10019	2N3565
A4Q28	10017	2N3569
A4Q29		Not Used
A4Q30		Not Used
A4Q31	10896	3N138
A4Q32	10896	3N138
A4Q33	10339	2N4360
A4Q34	10023	2N3644
A4Q35	10023	2N3644
A4Q36	10019	2N3565
A4Q37	10023	2N3644
A4Q38	10019	2N3565
A4Q39	10017	2N3569
A4Q40	10018	2N3646
A4Q41	10023	2N3644
A4Q42	10023	2N3644
A4Q43	10019	2N3565
A4Q44	10019	2N3565
A4Q45	10018	2N3646
A4QA1	10769	Motorola MC 1709CG (OP. AMPLIFIER)
A4R1	10013-57	Carbon Film 470 KΩ ± 5% 1/4 W
A4R2	10015-7	Metal Film 10 KΩ± 1% 1/8 W
A4R3	10013-9	Carbon Film 47 Ω ± 5% 1/4 W
A4R4	10015-7	Metal Film 10 KΩ± 1% 1/8 W
A4R5	10015-21	Metal Film 4.64 KΩ ± 1% 1/8 W
A4R6	10015-7	Metal Film 10 KΩ ± 1% 1/8 W
A4R7	10015-7	Metal Film 10 KΩ ± 1% 1/8 W
A4R8	10013-33	Carbon Film 4.7 KΩ ± 5% 1/4 W
A4R9	10013-65	Carbon Film 2.2 MΩ ± 5% 1/4 W
A4R10	10046-8	Variable Composition 10 KΩ ± 20% 1/4 W
A4R11	10013-39	Carbon Film 15 KΩ ± 5% 1/4 W
A4R12		Not Used
A4R13	10013-29	Carbon Film 2.2 KΩ ± 5% 1/4 W
A4R14	10013-37	Carbon Film 10 KΩ ± 5% 1/4 W
A4R15	10013-25	Carbon Film 1 KΩ ± 5% 1/4 W
A4R16	10013-13	Carbon Film 100 Ω ± 5% 1/4 W
A4R17	10015-65	Metal Film 4.99 KΩ ± 1% 1/8 W
A4R18	10013-41	Carbon Film 22 KΩ ± 5% 1/4 W
A4R19	10013-9	Carbon Film 47 Ω ± 5% 1/4 W
A4R20	10013-41	Carbon Film 22 KΩ ± 5% 1/4 W
A4R21	10013-45	Carbon Film 47 KΩ ± 5% 1/4 W
A4R22	10015-7	Metal Film 10 KΩ ± 1% 1/8 W
A4R23		Factory Selected Value
A4R24	10013-33	Carbon Film 4.7 KΩ ± 5% 1/4 W

CIRCUIT REFERENCE	PART NO.	DESCRIPTION
A4R25	10013-19	Carbon Film 330 Ω ± 5% 1/4 W
A4R26	10046-5	Variable Composition 2 KΩ ± 20% 1/4 W
A4R27	10013-41	Carbon Film 22 KΩ ± 5% 1/4 W
A4R28	10046-8	Variable Composition 10 KΩ ± 20% 1/4 W
A4R29	10013-29	Carbon Film 2.2 KΩ ± 5% 1/4 W
A4R30		Not Used
A4R31	10013-27	Carbon Film 1.5 KΩ ± 5% 1/4 W
A4R32	10013-29	Carbon Film 2.2 KΩ ± 5% 1/4 W
A4R33	10013-25	Carbon Film 1 KΩ ± 5% 1/4 W
A4R34	10013-1	Carbon Film 10 Ω ± 5% 1/4 W
A4R35	10013-5	Carbon Film 22 Ω ± 5% 1/4 W
A4R36	10013-25	Carbon Film 1 KΩ ± 5% 1/4 W
A4R37	10015-28	Metal Film 23.7 KΩ ± 1% 1/8 W
A4R38	10013-31	Carbon Film 3.3 KΩ ± 5% 1/4 W
A4R39	10013-25	Carbon Film 1 KΩ ± 5% 1/4 W
A4R40		Not Used
A4R41		Factory Selected
A4R42		Not Used
A4R43	10013-61	Carbon Film 1MΩ ± 5% 1/4 W
A4R44	10013-37	Carbon Film 10 KΩ ± 5% 1/4 W
A4R45	10013-73	Carbon Film 10 MΩ ± 5% 1/4 W
A4R46	10013-49	Carbon Film 100 KΩ ± 5% 1/4 W
A4R47	12449-22	Metal Film 2.50 KΩ 0.1% 1/8 W
A4R48	10015-7	Metal Film 10 KΩ ± 1% 1/8 W
A4R49	10013-11	Carbon Film 68 Ω ± 5% 1/4 W
A4R50	10015-7	Metal Film 10 KΩ ± 1% 1/8 W
A4R51	10013-33	Carbon Film 4.7 KΩ ± 5% 1/4 W
A4R52	10013-33	Carbon Film 4.7 KΩ ± 5% 1/4 W
A4R53	10013-33	Carbon Film 4.7 KΩ ± 5% 1/4 W
A4R54	10013-33	Carbon Film 4.7 KΩ ± 5% 1/4 W
A4R55	10013-9	Carbon Film 47 Ω ± 5% 1/4 W
A4R56	10013-9	Carbon Film 47 Ω ± 5% 1/4 W
A4R57	10013-33	Carbon Film 4.7 KΩ ± 5% 1/4 W
A4R58	10013-9	Carbon Film 47 Ω ± 5% 1/4 W
A4R59	10013-33	Carbon Film 4.7 KΩ ± 5% 1/4 W
A4R60	10013-37	Carbon Film 10 KΩ ± 5% 1/4 W
A4R61	10013-9	Carbon Film 47 Ω ± 5% 1/4 W
A4R62	10013-9	Carbon Film 47 Ω ± 5% 1/4 W
A4R63	10013-19	Carbon Film 330 Ω ± 5% 1/4 W
A4R64	10013-35	Carbon Film 6.8 KΩ ± 5% 1/4 W
A4R65	10013-49	Carbon Film 100 KΩ ± 5% 1/4 W
A4R66	10013-45	Carbon Film 47 KΩ ± 5% 1/4 W
A4R67	10013-37	Carbon Film 10 KΩ ± 5% 1/4 W
A4R68	10013-41	Carbon Film 22 KΩ ± 5% 1/4 W
A4R69	10013-45	Carbon Film 47 KΩ ± 5% 1/4 W
A4R70	10013-37	Carbon Film 10 KΩ ± 5% 1/4 W
A4R71	10013-25	Carbon Film 1 KΩ ± 5% 1/4 W
A4R72	10013-37	Carbon Film 10 KΩ ± 5% 1/4 W
A4R73	10013-25	Carbon Film 1 KΩ ± 5% 1/4 W
A4R74	10013-13	Carbon Film 100 Ω ± 5% 1/4 W
A4R75	10013-13	Carbon Film 100 Ω ± 5% 1/4 W
A4R76	10015-7	Metal Film 10 KΩ ± 1% 1/8 W
A4R77	10013-41	Carbon Film 22 KΩ ± 5% 1/4 W
A4R78	10013-9	Carbon Film 47 Ω ± 5% 1/4 W
A4R79	10013-41	Carbon Film 22 KΩ ± 5% 1/4 W
A4R80	10013-45	Carbon Film 47 KΩ ± 5% 1/4 W
A4R81	10013-37	Carbon Film 10 KΩ ± 5% 1/4 W
A4R82	10013-29	Carbon Film 2.2 KΩ ± 5% 1/4 W
A4R83	10013-11	Carbon Film 68 Ω ± 5% 1/4 W
A4R84	10013-27	Carbon Film 1.5 KΩ ± 5% 1/4 W
A4R85	10013-29	Carbon Film 2.2 KΩ ± 5% 1/4 W
A4R86	10013-1	Carbon Film 10 Ω ± 5% 1/4 W
A4R87	10015-26	Metal Film 154 KΩ ± 1% 1/8 W
A4R88	10015-12	Metal Film 9.09 KΩ ± 1% 1/8 W
A4R89	10046-5	Variable Composition 2 KΩ ± 20% 1/4 W
A4R90	10013-17	Carbon Film 220 Ω ± 5% 1/4 W
A4R91	10013-27	Carbon Film 1.5 KΩ ± 5% 1/4 W
A4R92		Not Used
A4R93	10013-25	Carbon Film 1 KΩ ± 5% 1/4 W
A4R94	10015-58	Metal Film 9.76 KΩ ±5% 1/8 W
A4R95	10046-1	Variable Composition 500 Ω ±20% 1/4 W
A4R96	10013-49	Carbon Film 100 KΩ ± 5% 1/4 W
A4R97	10013-45	Carbon Film 47 KΩ ± 5% 1/4 W
A4R98	10013-73	Carbon Film 10 MΩ ± 5% 1/4 W
A4R99	10013-41	Carbon Film 22 KΩ ± 5% 1/4 W
A4R100	10013-7	Carbon Film 33 Ω ± 5% 1/4 W
A4R101	10013-29	Carbon Film 2.2 KΩ ± 5% 1/4 W
A4R102	10013-29	Carbon Film 2.2 KΩ ± 5% 1/4 W
A4R103	10013-19	Carbon Film 330 Ω ± 5% 1/4 W
A4R104	10013-19	Carbon Film 330 Ω ± 5% 1/4 W
A4R105	10013-21	Carbon Film 470 Ω ± 5% 1/4 W
A4R106	10013-25	Carbon Film 1 KΩ ± 5% 1/4 W
A4R107	10013-25	Carbon Film 1 KΩ ± 5% 1/4 W
A4R108	10013-41	Carbon Film 22 KΩ ± 5% 1/4 W
A4R109	10013-25	Carbon Film 1 KΩ ± 5% 1/4 W
A4R110	10013-45	Carbon Film 47 KΩ ± 5% 1/4 W
A4R111	10013-7	Carbon Film 33 Ω ± 5% 1/4 W
A4R112	10013-21	Carbon Film 470 Ω ± 5% 1/4 W
A4R113	10013-33	Carbon Film 4.7 KΩ ± 5% 1/4 W
A4R114	10013-25	Carbon Film 1 KΩ ± 5% 1/4 W
A4R115	10013-57	Carbon Film 470 KΩ ± 5% 1/4 W
A4R116	10013-37	Carbon Film 10 KΩ ± 5% 1/4 W
A4R117	10013-47	Carbon Film 68 KΩ ± 5% 1/4 W
A4R118	10013-41	Carbon Film 22 KΩ ± 5% 1/4 W
A4R119	10013-33	Carbon Film 4.7 KΩ ± 5% 1/4 W
A4R120	10013-27	Carbon Film 1.5 KΩ ± 5% 1/4 W
A4R121	10013-45	Carbon Film 47 KΩ ± 5% 1/4 W
A4R122	10013-47	Carbon Film 68 KΩ ± 5% 1/4 W
A4R123	10013-27	Carbon Film 1.5 KΩ ± 5% 1/4 W
A4R124	10013-53	Carbon Film 220 KΩ ± 5% 1/4 W
A4R125	10013-53	Carbon Film 220 KΩ ± 5% 1/4 W
A4R126	10013-49	Carbon Film 100 KΩ ± 5% 1/4 W
A4R127	10013-41	Carbon Film 22 KΩ ± 5% 1/4 W
A4R128	10013-39	Carbon Film 15 KΩ ± 5% 1/4 W
A4R129	10013-37	Carbon Film 10 KΩ ± 5% 1/4 W
A4R130	10725-2	Precision Wirewound 5.00 KΩ ± 0.05% 1/4 W
A4R131	12449-32	Metal Film 1.250 KΩ ± 0.1% 1/8 W
A4R132	10015-79	Metal Film 2.67 KΩ ± 1% 1/8 W
A4R133	10015-35	Metal Film 1.78 KΩ ± 1% 1/8 W
A4R134	10013-9	Carbon Film 47Ω ± 5% 1/4 W
A4R135	10013-29	Carbon Film 2.2 KΩ ± 5% 1/4 W
A4R136	10013-35	Carbon Film 6.8 KΩ ± 5% 1/4 W
A4R137	12449-22	Metal Film 2.50 KΩ ± 0.1% 1/8 W
A4R138	12449-38	Metal Film 22.50 KΩ + 0.1% 1/8 W
A4R139	10015-90	Metal Film 24.9 KΩ ± 1% 1/8 W
A4R140	12449-43	Metal Film 225 KΩ ± 0.1% 1/8 W
A4R141	10015-102	Metal Film 249 KΩ ± 1% 1/8 W
A4R142	10015-102	Metal Film 249 KΩ ± 1% 1/8 W
A4R143	12449-43	Metal Film 225 KΩ ± 0.1% 1/8 W
A4R144	12449-34	Metal Film 2.808 KΩ ± 0.1% 1/8 W
A4R145	12449-40	Metal Film 24.96 KΩ ± 0.1% 1/8 W
A4R146	12449-32	Metal Film 1.250 KΩ ± 0.1% 1/8 W
A4R147	10725-2	Precision Wirewound 5.00 KΩ ± 0.05% 1/4 W
A4R148	10015-7	Metal Film 10.0 KΩ ± 1% 1/8 W

CIRCUIT REFERENCE	PART NO.	DESCRIPTION
A4R149	10015-60	Metal Film 19.6 KΩ ± 1% 1/8 W
A4R150	10015-58	Metal Film 9.76 KΩ ± 1% 1/8 W
A4R151	10046-1	Variable Composition 500 Ω ± 20% 1/4 W
A4R152	10725-1	Precision Wirewound 4.00 KΩ ± .05% 1/8 W
A4R153	10015-11	Metal Film 16.2 KΩ ± 1% 1/8 W
A4R154	10013-27	Carbon Film 1.5 KΩ ± 5% 1/4 W
A4R155	10013-1	Carbon Film 10 Ω ± 5% 1/4 W
A4R156		Not Used
A4R157	10013-1	Carbon Film 10Ω ± 5% 1/4 W
A4R158	10013-1	Carbon Film 10Ω ± 5% 1/4 W
A4R159	10013-1	Carbon Film 10Ω ± 5% 1/4 W
A4R160		Not Used
A4R161	10013-1	Carbon Film 10Ω ± 5% 1/4 W
A4R162	10013-1	Carbon Film 10Ω ± 5% 1/4 W
A4R163	10013-37	Carbon Film 10 KΩ ± 5% 1/4 W
A4R164	10013-27	Carbon Film 1.5 KΩ ± 5% 1/4 W
A4R165	10013-39	Carbon Film 15 KΩ ± 5% 1/4 W
A4R166	10013-31	Carbon Film 3.3 K ± 5% 1/4 W
A4R167	10013-57	Carbon Film 470 KΩ ± 5% 1/4 W
A4R168	10046-10	Variable Composition 100 KΩ ± 20% 1/4 W
A4R169	10013-33	Carbon Film 4.7 KΩ ± 5% 1/4 W
A4R170	10013-29	Carbon Film 2.2 KΩ ± 5% 1/4 W
A4R171	10013-23	Carbon Film 680 Ω ± 5% 1/4 W
A4R172	10013-49	Carbon Film 100 KΩ ± 5% 1/4 W
A4R173	10013-73	Carbon Film 10 MΩ ± 5% 1/2 W
A4R174	10013-61	Carbon Film 1 MΩ ± 5% 1/4 W
A4R175	10046-10	Variable Composition 100 KΩ ± 20% 1/4 W
A4R176	10013-57	Carbon Film 470 KΩ ±5%
A4R177	10046-10	Variable Composition 100 KΩ ± 20% 1/4 W
A4R178	10013-1	Carbon Film 10 Ω ± 5% 1/4 W
A4R179	10013-37	Carbon Film 10 KΩ ± 5% 1/4 W
A4R180	10013-37	Carbon Film 10 KΩ ± 5% 1/4 W
A4RT1	10209	Thermistor 100 KΩ ± 10%
A4S1	11533	Switch, Push Button 8 Section

CIRCUIT REFERENCE	PART NO.	DESCRIPTION
		RECTIFIER AND UNIT LIGHT DRIVER PC BOARD ASSEMBLY - 10748
A5C1	10003-7	Electrolytic 1000 µF 35 VDC
A5C2	10003-7	Electrolytic 1000 µF 35 VDC
A5C3	10003-4	Electrolytic 20 µF 350 VDC
A5C4	10003-3	Electrolytic 4000 µF 15 VDC
A5CR1	10044-1	1N4383
A5CR2	10044-1	1N4383
A5CR3	10044-1	1N4383
A5CR4	10044-1	1N4383
A5CR5	10044-1	1N4383
A5CR6	10044-1	1N4383
A5CR7	10044-1	1N4383
A5CR8	10044-1	1N4383
A5CR8	10044-1	1N4383
A5CR9	10044-1	1N4383
A5CR10	10044-1	1N4383
A5CR11	10044-1	1N4383
A5CR12	10044-1	1N4383
A5CR13	10044-1	1N4383
A5CR14	10044-1	1N4383
A5CR15	10044-1	1N4383
A5CR16	10044-1	1N4383
A5CR17	10044-1	1N4383
A5CR18	10044-1	1N4383
A5Q1	10023	2N3644
A5Q2	10023	2N3644
A5Q3	10023	2N3644
A5Q4	10023	2N3644
A5R1	10013-31	Carbon Film 3.3 KΩ ± 5% 1/4 W
A5R2	10013-37	Carbon Film 10 KΩ ± 5% 1/4 W
A5R3	10013-9	Carbon Film 47 Ω ± 5% 1/4 W
A5R4	10013-41	Carbon Film 22 KΩ ± 5% 1/4 W
A5R5	10013-31	Carbon Film 3.3 KΩ ± 5% 1/4 W
A5R6	10013-37	Carbon Film 10 KΩ ± 5% 1/4 W
A5R7	10013-9	Carbon Film 47 Ω ± 5% 1/4 W
A5R8	10013-41	Carbon Film 22 KΩ ± 5% 1/4 W
A5R9	10013-31	Carbon Film 3.3 KΩ ± 5% 1/4 W
A5R10	10013-37	Carbon Film 10 KΩ ± 5% 1/4 W
A5R11	10013-9	Carbon Film 47 Ω ± 5% 1/4 W
A5R12	10013-41	Carbon Film 22 KΩ ± 5% 1/4 W
A5R13	10013-31	Carbon Film 3.3 KΩ ± 5% 1/4 W
A5R14	10013-37	Carbon Film 10 KΩ ± 5% 1/4 W
A5R15	10013-9	Carbon Film 47 Ω ± 5% 1/4 W
A5R16	10013-41	Carbon Film 22 KΩ ± 5% 1/4 W
A5R17	10013-33	Carbon Film 4.7 KΩ ± 5% 1/4 W
A5R18	10013-57	Carbon Film 470 KΩ ± 5% 1/4 W

CIRCUIT REFERENCE	PART NO.	DESCRIPTION
		CALIBRATOR PC BOARD ASSEMBLY 11391
A6C1	10000-6	Ceramic .0047 µF ±20% 500 VDC
A6C2	10000-6	Ceramic .0047 µF ±20% 500 VDC
A6C3	10000-6	Ceramic .0047 µF ±20% 500 VDC
A6C4	10585-3	Ceramic 470 pF ±5% 1000 VDC
A6C5	10000-6	Ceramic .0047 µF ±20% 500 VDC
A6C6	10000-6	Ceramic .0047 µF ±20% 500 VDC
A6C7		Factory Selected Value
A6C8	10000-1	Ceramic 100 pF ±20% 1000 VDC
A6C9	10000-1	Ceramic 100 pF ±20% 1000 VDC
A6C10	10000-1	Ceramic 100 pF ±20% 1000 VDC
A6C11	10000-7	Ceramic .01 µF ±20% 500 VDC
A6C12	10000-5	Ceramic .0022 µF ±20% 1000 VDC
A6C13	10000-6	Ceramic .0047 µF ±20% 500 VDC
A6CR1	11345	HPA 2900
A6CR2	11345	HPA 2900
A6CR3	10043	1N914A
A6CR4	10043	1N914A
A6L1	10631-5	10 µH ± 10%
A6L2	10631-3	.47 µH ± 10%
A6Q1	10018	2N3646
A6Q2	11119	2N4250
A6Q3	11119	2N4250
A6R1	10013-11	Carbon Film 68Ω ±5% 1/4 W
A6R2	10015-152	Metal Film 332Ω ±1% 1/8 W
A6R3	10015-151	Metal Film 59.0Ω ±1% 1/8 W
A6R4	10013-15	Carbon Film 150Ω ±5% 1/4 W
A6R5	10013-37	Carbon Film 10 KΩ ±5% 1/4 W
A6R6	10013-17	Carbon Film 220Ω ±5% 1/4 W
A6R7	10013-29	Carbon Film 2.2KΩ ±5% 1/4 W
A6R8	10013-37	Carbon Film 10KΩ ±5% 1/4 W
A6R9	10013-25	Carbon Film 1KΩ ±5% 1/4 W
A6R10	10013-29	Carbon Film 2.2KΩ ±5% 1/4 W
A6R11	10013-13	Carbon Film 100Ω ±5% 1/4 W
A6R12	10015-110	Metal Film 3.01KΩ ±1% 1/8 W
A6R13	10046-7	Variable 1KΩ ±20% 1/4 W
A6R14	10015-110	Metal Film 3.01KΩ ±1% 1/8 W
A6R15	10013-37	Carbon Film 10KΩ ±5% 1/4 W
		DETECTOR ASSEMBLY - 10778
A7C1	11573-1	Ceramic .001 µF ± 20% 50 V
A7CR1	10922	Diode Replacement Kit consisting of the following items: Detector element, capsule spacer, capacitive washer, R5, A4R41 and A4R23.
A7R1	11518-2	Metal Film 1.00KΩ ±1% 1/8W
A7RT1	10840	75 KΩ ±20%
	10777	Replacement Detector Cap Assembly includes Contact Assembly, A7C1, A7R1, A7RT1 and cable.
	11453	Replacement Detector Assembly consists of Detector Assembly 10778 with cable and resistors R5, A4R41 and A4R23.

CIRCUIT REFERENCE	PART NO.	DESCRIPTION
		RATIO/MARKER INPUT PC BOARD ASSEMBLY - 10913
A8C1	10000-1	Ceramic 100 pF ±20%
A8C2	10000-1	Ceramic 100 pF ±20%
A8C3	10000-10	Ceramic 0.1 µF +80-20% 100 VDC
A8C4	10000-10	Ceramic 0.1 µF +80-20% 100 VDC
A8CR1	10043	1N914A
A8Q1	11432	FM3955 (National)
A8Q2	10019	2N3565
A8Q3	10023	2N3644
A8R1	10013-25	Carbon Film 1KΩ ±5% 1/4 W
A8R2	10013-61	Carbon Film 1MΩ ±5% 1/4 W
A8R3	10013-25	Carbon Film 1KΩ ±5% 1/4 W
A8R4	10013-27	Carbon Film 1.5KΩ ±5% 1/4 W
A8R5	10013-17	Carbon Film 220Ω ±5% 1/4 W
A8R6	10013-1	Carbon Film 10Ω ±5% 1/4 W
A8R7	10013-33	Carbon Film 4.7KΩ ±5% 1/4 W
A8R8	10013-1	Carbon Film 10Ω ±5% 1/4 W
A8R9	10013-35	Carbon Film 6.8KΩ ±5% 1/4 W
A8R10	10013-27	Carbon Film 1.5KΩ ±5% 1/4 W

PART NO. CROSS REFERENCE		
PART NO.	MFGR. CODE	MFGR. PART NO.
10000-1	56289	5GA-T10
10000-2	56289	5GA-T22
10000-3	56289	5GA-T47
10000-4	56289	5GA-D10
10000-5	56289	5GA-D22
10000-6	56289	5GA-D47
10000-7	56289	5GA-S10
10000-8	56389	5GAS-S20
10000-10	91418	Type TA 0.1 µF
10001-2	56289	10 TCC-V47
10001-3	56289	10 TCC-Q10
10001-5	56289	10 TCC-Q33
10001-6	56289	10 TCC-Q47
10001-12	56289	10 TCC-V33
10003-3	12674	EMW-2468
10003-4	56289	TVA-1608
10003-7	25088	B41010-1000-40-8212
10007-1	01002	75F1R2A 102
10007-5	01002	75F1R2A 223
10007-7	01002	75F3R2A 104
10013-1	80031	B803 104NB 100
10013-5	80031	B803 104NB 220
10013-7	80031	B803 104NB 330
10013-9	80031	B803 104NB 470
10013-11	80031	B803 104NB 680
10013-13	80031	B803 104NB 101
10013-15	80031	B803 104NB 151
10013-17	80031	B803 104NB 221
10013-19	80031	B803 104NB 331
10013-21	80031	B803 104NB 471
10013-23	80031	B803 104NB 681
10013-25	80031	B803 104NB 102
10013-27	80031	B803 104NB 152
10013-29	80031	B803 104NB 222
10013-31	80031	B803 104NB 332
10013-33	80031	B803 104NB 472
10013-35	80031	B803 104NB 682
10013-37	80031	B803 104NB 103
10013-39	80031	B803 104NB 153
10013-41	80031	B803 104NB 223
10013-43	80031	B803 104NB 333
10013-45	80031	B803 104NB 473
10013-47	80031	B803 104NB 683
10013-49	80031	B803 104NB 104
10013-53	80031	B803 104NB 224
10013-57	80031	B803 104NB 474
10013-61	80031	B803 104NB 105

PART NO. CROSS REFERENCE		
PART NO.	MFGR. CODE	MFGR. PART NO.
10013-65	01121	CB2255
10013-68	01121	CB3955
10013-73	01121	CB1065
10013-74	01121	CB2055
10015-1	91637	RN55D, 1.54 KΩ 1%
10015-3	91637	RN55D, 49.9 Ω 1%
10015-7	91637	RN55D, 10.0 KΩ 1%
10015-11	91637	RN55D, 16.2 KΩ 1%
10015-12	91637	RN55D, 9.09 KΩ 1%
10015-13	91637	RN55D, 100 KΩ 1%
10015-21	91637	RN55D, 4.64 KΩ 1%
10015-24	91637	RN55D, 46.4 KΩ 1%
10015-25	91637	RN55D, 61.9 KΩ 1%
10015-26	91637	RN55D, 154 KΩ 1%
10015-29	91637	RN55D, 422 Ω 1%
10015-35	91637	RN55D, 1.78 KΩ 1%
10015-40	91637	RN55D, 43.2 KΩ 1%
10015-45	91637	RN55D, 499 KΩ 1%
10015-46	91637	RN55D, 249 Ω 1%
10015-50	91637	RN55D, 1.47 KΩ 1%
10015-57	91637	RN55D, 8.66 KΩ 1%
10015-58	91637	RN55D, 9.76 KΩ 1%
10015-59	91637	RN55D, 10.5 KΩ 1%
10015-60	91637	RN55D, 19.6 KΩ 1%
10015-62	91637	RN55D, 200 KΩ 1%
10015-63	91637	RN55D, 402 KΩ 1%
10015-65	91637	RN55D, 4.99 KΩ 1%
10015-68	91637	RN55D, 100 Ω 1%
10015-69	91637	RN55D, 196 Ω 1%
10015-70	91637	RN55D, 681 Ω 1%
10015-71	91637	RN55D, 909 Ω 1%
10015-72	91637	RN55D, 1.96 KΩ 1%
10015-79	91637	RN55D, 2.67 KΩ 1%
10015-90	91637	RN55D, 24.9 KΩ 1%
10015-102	91637	RN55D, 249 KΩ 1%
10015-103	91637	RN55D, 66.5 Ω 1%
10015-110	91637	RN55D, 3.01 KΩ 1%
10015-151	91637	RN55D, 59.0 Ω 1%
10015-152	91637	RN55D, 332 Ω 1%
10017	07263	2N3569
10018	07263	2N3646
10019	07263	2N3565
10020	02735	40250
10022	07263	2N3640
10023	07263	2N3644
10043	07263	1N914A
10044-1	11711	1N4383

PART NO. CROSS REFERENCE		
PART NO.	MFGR. CODE	MFGR. PART NO.
10045	07910	1N823
10046-1	71450	X201R501B
10046-5	71450	X201R202B
10046-6	71450	X201R201B
10046-7	71450	X201R102B
10046-8	71450	X201R103B
10046-9	71450	X201R101B
10046-10	71450	X201R104B
10048	02660	31-221-1050
10050-1	02660	225-21513-101
10052	82389	AC3G
10054-1	74970	105-0703-001
10054-2	74970	105-0702-001
10054-3	74970	105-0710-001
10057	09353	7201
10059	79727	G-126
10060-3	91802	2190B42
10064-2	75915	312-500
10065	75915	357001
10095-2	71450	Series 45, 1 KΩ
10140-1	74970	105852
10140-2	74970	105857
10142-2	01121	CB1565
10142-4	01121	CB2265
10206	07263	2N3053
10207	16170	SU2080
10209	90634	51RD21
10217	28821	10217
10312	01295	2N2917
10339	07263	2N4360
10398	07263	2N4917
10450	76854	399163-184
10585-3	28821	10585-3
10631-3	99800	1025-12
10631-5	99800	1025-44
10712-1	31918	55306V 10mA
10722-1	04713	MC724P
10722-2	04713	MC725P
10722-3	04713	MC788P
10722-4	04713	MC789P
10722-5	04713	MC790P
10722-6	04713	MC792P
10723	83594	B-5441
10724	83594	B-5442
10725-1	22045	J110, 4.00 KΩ 0.05%
10725-2	22045	J110, 5.00 KΩ 0.05%
10727-1	14298	EE 1/8-C2 40 KΩ 0.5%

PART NO. CROSS REFERENCE		
PART NO.	MFGR. CODE	MFGR. PART NO.
10727-2	14298	EE 1/8-C2 50 KΩ 0.5%
10728	07263	U6B996079
10743	04713	MC1709CL
10761	14433	1N279
10769	04713	MC1709CG
10777	28821	10777
10787-2	12954	D12GSB 20M
10787-3	12954	D27GSB 15M
10787-4	12954	D68GSC 15M
10791	28821	10791
10821	02660	Type N, UG-58A/U
10840	83186	48A12
10885	01295	1N957B
10896	02735	3N138
10922	28821	10922
11119	07263	2N4250
11345	28480	HPA-2900
11432	27014	FM3955
11450	04713	1N957B (selected)
11453	28821	11453
11457	07263	2N3646 (selected)
11507	01295	TIS97
11533	28821	11533
11518-2	91637	RN55D, 1 KΩ 1%
11573-1	71590	CW15C 102 M
11676-2	01121	WA1G012S503MZ
11676-4	01121	WA1G012S202MZ
11692	07263	2N5833
12449-21	14298	EE 1/8-C2 10.00 KΩ 0.1%
12449-22	14298	EE 1/8-C2 2.500 KΩ 0.1%
12449-32	14298	EE 1/8-C2 1.250 KΩ 0.1%
12449-34	14298	EE 1/8-C2 2.808 KΩ 0.1%
12449-37	14298	EE 1/8-C2 20.00 KΩ 0.1%
12449-38	14298	EE 1/8-C2 22.50 KΩ 0.1%
12449-40	14298	EE 1/8-C2 24.96 KΩ 0.1%
12449-43	14298	EE 1/8-C2 225.0 KΩ 0.1%
13533	04713	2N2907/2N2907A
13543	04713	2N2221/2N2221A

(B)

FEDERAL SUPPLY CODE FOR MANUFACTURERS

The following five-digit code numbers are listed in numerical sequence along with the manufacturer's name and address to which the code has been assigned.

The Federal Supply Code has been taken from Cataloging Handbook H 4-2, Code to Name.

00303	Shelly Associates Inc. El Segundo, California.
00656	Aerovox Corp. New Bedford, Massachusetts
00779	AMP Inc. Harrisburg, Pennsylvania
01002	General Electric Co. Capacitor Dept. Hudson Falls, New York
01121	Allen-Bradley Co. Milwaukee, Wisconsin
01295	Texas Instruments, Inc. Semiconductor Components Div. Dallas, Texas
01961	Pulse Engineering Inc. Santa Clara, California
02114	Ferroxcube Corp. of America Saugerties, New York
02660	Amphenol-Borg Elect. Corp. Broadview, Illinois
02735	Radio Corp. of America Semiconductor and Materials Div. Somerville, New Jersey
04062	Elmenco Products Co. New York, N.Y.
04713	Motorola, Inc. Semiconductor Products Div. Phoenix, Arizona
07263	Fairchild Camera and Inst. Corp. Semiconductor Div. Mountain View, California
07910	Continental Device Corp. Hawthorne, California
09214	General Electric Co. Semiconductor Products Dept. Auburn, New York
09353	C and K Components Inc. Newton, Massachusetts
11711	General Instruments Inc. Semiconductor Div. Newark, New Jersey
12674	Syncro Corp. Hicksville, Ohio
12954	Dickson Electronics Corp. Scottsdale, Arizona
14298	American Components, Inc. Conshohocken, Pennsylvania
18324	Signetics Corp. Sunnyvale, Calif.
24931	Speciality Connector Co. Inc. Indianapolis, Indiana
25088	Siemens America Corp. Iselin, New Jersey
27014	National Semiconductor Corp. Santa Clara, California
27556	IMB Electronic Products Santa Fe Springs, California
28480	Hewlett-Packard Co. Palo Alto, California
28821	Pacific Measurements Inc. Palo Alto, California
56289	Sprague Electric Co. North Adams, Massachusetts
71034	Bliley Electric Co. Erie, Pa.
70903	Belden Mfg. Co. Chicago, Illinois
71400	Bussman Mfg. Div. of McGraw-Edison Co. St. Louis, Missouri
71450	CTS Corp. Elkhart, Indiana
72982	Erie Tech. Products Inc. Erie, Pennsylvania
73138	Beckman Instruments Inc. Helipot Division Fullerton, California